THE ADVANCE ON CHINA COASTAL ENGINEERING

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An overall introduction is made in this paper to the progress of coastal engineering in the mainland of China during the last two decades, covering the regulation engineering and training effects of the deep navigation channel of the Yangtze River estuary and the Pearl River estuary; the coast protection standards, beach protection and reclamation engineering as well as various types of structures; ports construction and development; the key technology achievements in hydrodynamics of the silty and sand coasts and radial sandbanks; and the main technological development of several large-size cross-sea bridges. It is pointed out that China needs to improve the coastal hydrodynamic monitoring system, to solve the key problems in the coastal engineering construction under severe environment conditions, and to strengthen the management and ecological protection of coastal zones.

Keywords: china coastal engineering; technology progress；perspective;

INTRODUCTION

The territory of China extends across the tropical, subtropical and temperate climate zones, and borders on the Yellow Sea, the East China Sea, the South China Sea and the sea area in the east of Taiwan, and Bohai Sea is an inland sea of China.

The coastline of China is about 37,000 km long, in which the mainland coastline is more than 18,000 km and the island coastline about 19,000 km. Nearly one thousand rivers along the coast flow into the sea. The mainland coastline is situated at the subtropical zone with the widest range, accounting for 60% of the total coastline length. The climatic conditions of South China and North China along the coast have an obvious difference. There is an ice period of about 2 to 3 months each year in Bohai Sea and in the Northern part of Yellow Sea, but most of the other coastal zones are neither ice cold in winter nor heavy hot in summer. The tidal waves from the Pacific Ocean, entering into upper four marginal seas, transform under the influence of coast, bay or gulf, estuary and island, the tide types are very complex and the largest tidal range exists in East China Sea and the smallest in South China Sea.

The following comprehensive geomorphic features taken into consideration, such as form of coast, cause of formation, material composition and development and evolution phases, the sea coasts of China can be categorized into rocky, sandy gravel, silty sand, silt, mangrove, coral reef and other types. These different types of coasts result in the diversified features of China coastal engineering.

The storm disaster frequently attacks the coasts in mainland China. Being affected by the tropical storm (including the typhoon) from Northwest Pacific and the Subtropical high pressure of Western Pacific in summer and autumn and by the temperate cyclone in winter and spring, the storm surge occurs over 10 times on average annually, bringing serious loss to the social economy along the coastal areas.

The construction of China coastal engineering has experienced the great development period at different stages, like the late 1950s, the early 1970s and the middle 1980s, and especially since the middle 1990s, it has made amazingly magnificent achievements. This paper introduces the progress of mainland China coastal engineering during the past two decades from the aspects of estuary regulation, coast protection and sea reclamation works, harbor works and sea-crossing bridge works, to name a few.

ESTUARY REGULATION WORKS

The Regulation Project of the Deep Navigation Channel of Yangtze Estuary

Overview. The Yangtze Estuary is characterized by three-order bifurcation and four outlets into the sea. In each outlet entering into the sea exists the “sand bar”, of which the natural water depth is far shallower than its upper and lower reaches, and the natural water depth on the top of sand bar is nearly 6.0 m. Before the regulation project is executed, the north branch has gradually silted up, used to small boats navigation; and the North Channel and South Passage are still the natural channels with water depth of 6.0 m; the North Passage keeps a 7.0 m navigable water through dredging, and only about

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15,000-ton vessels can pass it using the tide averagely each day, thereby becoming a bottleneck for the marine transport of the ports at the lower reaches of Yangtze River and the Port of Shanghai. In 1997, the government approved the implementation of the Yangtze Estuary Deepwater Channel Regulation Project (in three stages) and then the water depth of navigation channel was increased to 8.5 m, 10 m and 12.5 m by stages, so as to meet the needs of the third and fourth generations of container ships entering and leaving the Yangtze Estuary all-weather condition, and the fifth and sixth generations of container ships and 100,000DWT bulk carriers and oil tankers entering and leaving the Yangtze Estuary with the tide.

Main works. The regulation principle of the project is to combine regulation with dredging. The main regulation works is to construct a north and a south jetty and a series of spur dikes at the North Passage of the Yangtze Estuary, in which the south jetty is 48.1 km long and the north one is 49.2 km long, and the top elevation of jetty is on the mean tide level. Totally 19 spur dikes are constructed inside the south and the north jetties (Figure 1).

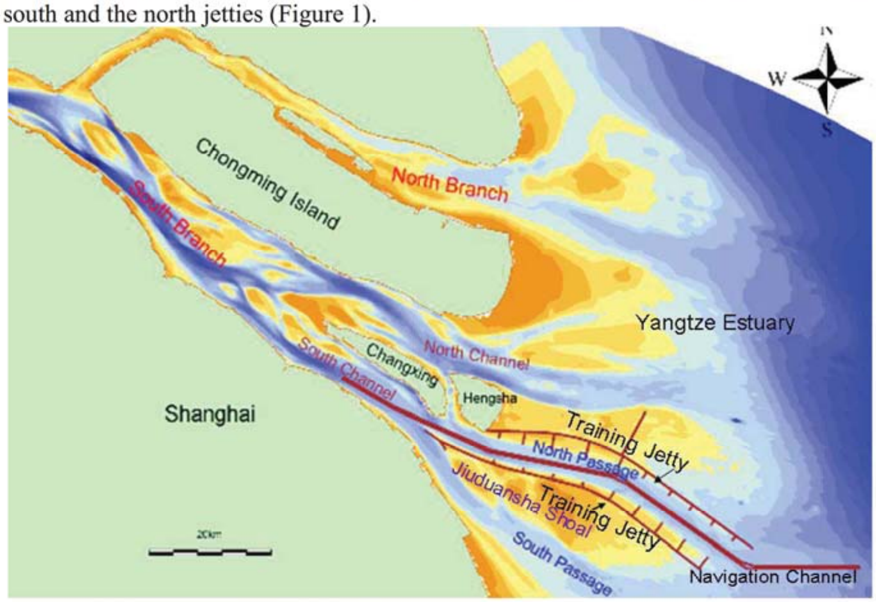


Figure 1. Layout plan of the Yangtze Estuary and its deep navigation channel regulation project.

Main technical progress (Yangtze Estuary Waterway Administration Bureau 2007)

(1) The simulation technology of hydrodynamic and sediment transport.

A numerical model of combined load (suspended load and bed load) for the Yangtze Estuary under the combined action of multiple complex factors such as runoff, tidal currents, waves and saline water has been established, to forecast the siltation and its distribution in the channel with different periods, as well as the short term siltation of channel under the adverse condition that violent typhoons meet astronomical spring tides and major floods, and solve the technical problem on siltation forecast of the channels at the Yangtze Estuary. Also in the large scale tidal currents physical model of the estuary, the simulation technology for the movable bed scour test and suspended load deposition test have been successfully realized (Chen et al. 2005).

(2) Structural forms of the regulating structures.

a. Geotextile mattress for bottom protection and sloping dike with bagged sand core.

The bottom protection adopts needle-punched composite geotextile, combined with two kinds of ballast materials, i.e. long tube sand rib and concrete interlocking block, so as to solve effectively the design problem on sea bed protection width (Figure 2-1). The design of geotextile bagged sand core in sloping dike structure has gained the successful experience from the domestic seawall slope protection works and the experiences from several serious wind damage works, and has taken many new measures in increasing the stability of the structure under wave action. In the second stage of the project, the fabriform concrete capping structure is changed into armour unit (Figure 2-2).

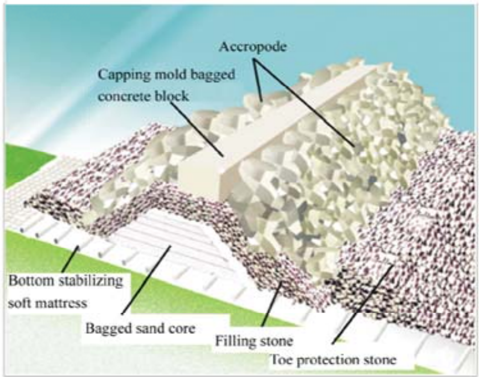


Figure 2-1. Typical structure diagram of bagged sand sloping jetty in Phase I.

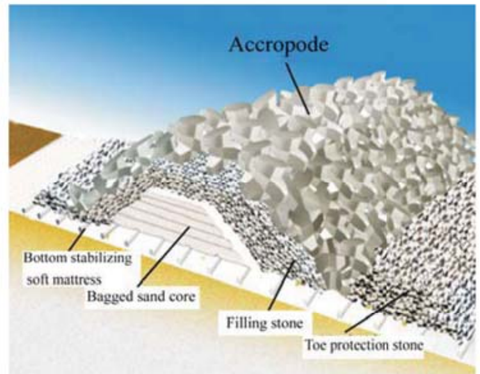
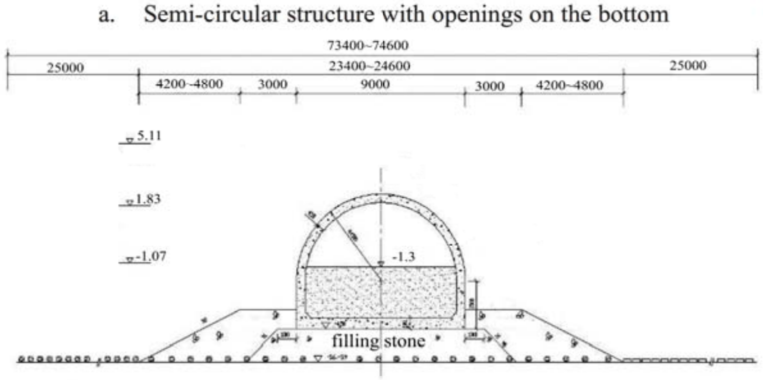


Figure 2-2. Typical structure diagram of bagged sand sloping jetty in Phase II.

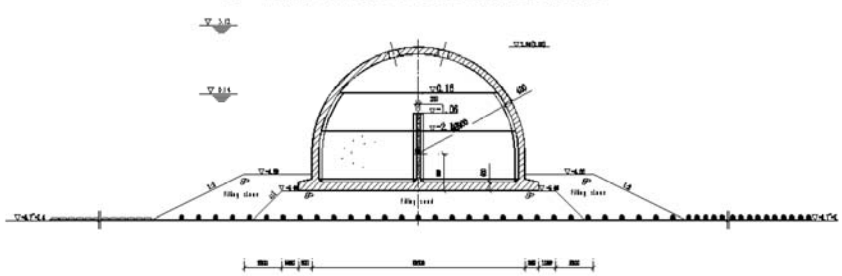
b. New semi-circular structure and design method.

Completed the main improvement of Japanese semi- circular structure, a semi-circular structure with perforated plate on the bottom, a sand-filled semi-circular structure and a semi-circular caisson structure are developed, so as to provide more convenient construction conditions and to reduce the construction costs. It is widely used in the regulation projects (Figure 3).

a. Semi-circular structure with openings on the bottom



b. Sand-filled semi-circular structure



c. Semi-circular caisson structure

Figure 3. Typical section of the semi-circular caisson structure.

c. New hollow-block mound breakwater structure and design method.

In order to meet the requirements for the bearing capacity of the ultra-soft foundation and the overall stability of the structure at the head of north jetty in the second stage of the project, the jetty body is randomly stacked by the reinforced concrete hollow cubic blocks with side length of 2.5 m and single-piece weight of 14.4 t. The weight of the jetty body with the reinforced concrete hollow cubic blocks is only about 30% of the rubble ones. Totally 27,028 hollow blocks are used in the second stage of the project, and the built jetty is 3.08 km long. The monitoring result of this section indicates that this breakwater is stable by the attack of typhoon waves for several times (Figure 4-1 and Figure 4-2).

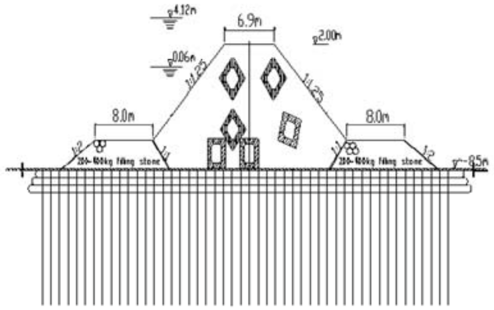


Figure 4-1. Sectional view of hollow-block mound Breakwater.

Figure 4-2. Built hollow-block mound breakwater.

d. The soil anti-softening engineering measures and the anti-skid structure under wave actions.

With respect to the abnormal settlement failure at the part of caisson section of the second stage of the project, the anti-softening engineering measure is taken, mainly featured by the preliminary implementation of drainage and consolidation for the easily softened soil layer (Figure 5). And the rubber anti-sliding plates are arranged under the semi-circular caisson, to increase the friction coefficient between the jetty structure and the rubble mound foundation satisfy the requirements for the bearing capacity and overall stability of the foundation after dynamic softening.

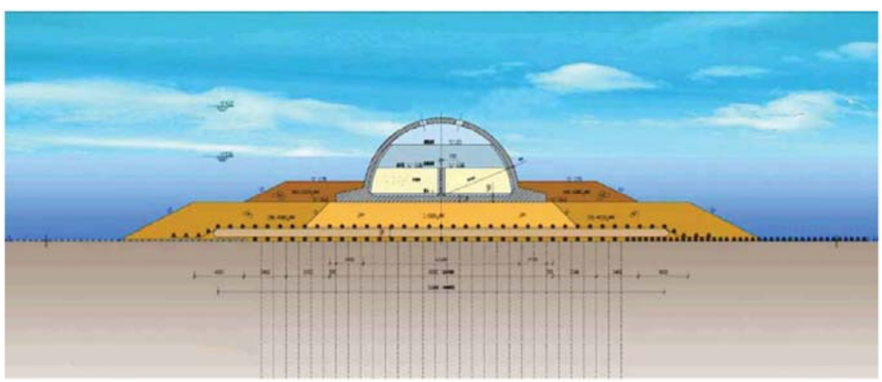


Figure 5. Typical design sectional view of the anti-softening engineering measure.

Engineering effect. In March 2010, the third stage of the Yangtze Estuary Deepwater Channel passed the Project Completion Evaluation by the Ministry of Communication (MOC), which means that the Yangtze Estuary Deepwater Channel Regulation Project has been successfully completed after the effort lasted 12 years.

After the third stage of the project is executed, the water depth is obviously improved (Fan 2010). Currently, the average water depth of the navigation channel at the Yangtze Estuary may keep 12.5 m (Figure 6). An increase of 4 million TEU of containers can enter and leave the Port of Shanghai each year; passed large vessels of 50,000 DWT or above are increased to 4,500 vessels per year, increasing by 37.6% than that before the 10.0 m channel is opened. The implementation of this project plays an important role in making Shanghai to be a significant port with the world's largest cargo handling capacity, and the third-busiest container throughput and maintaining that third place in the world, and the project also greatly promotes the economic development along the Yangtze River.

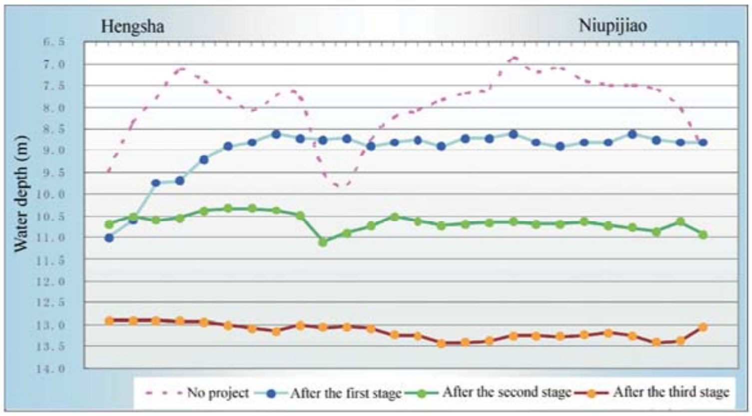


Figure 6 Change of bottom level profile in the channel before and after the training project.

Pearl River Estuary Channel Regulation Project

Pearl River is the third largest river in China, and its estuary presents the pattern of "the junction of three rivers and eight outlets into the sea". The confluence of water and sediment from the West River, the North River and the East River flow into the sea through eight outlets of the Pearl River Delta. These eight outlets are divided into the east and west parts by geographical distribution (Figure 7). The four outlets in the east part enter to Lingdingyang Bay.

Lingdingyang Bay is horn-shaped bay, and its trend is close to NNW-SSE direction. The bay head is about 4 km wide and the bay mouth is about 30 km wide; and the bay is 72 km long in longitudinal direction and covers a basin area of 2110 km^2.The underwater topography represents the basic pattern of "three beaches and two passages" (Figure 8). There are also some islands in the bay of Lingdingyang,

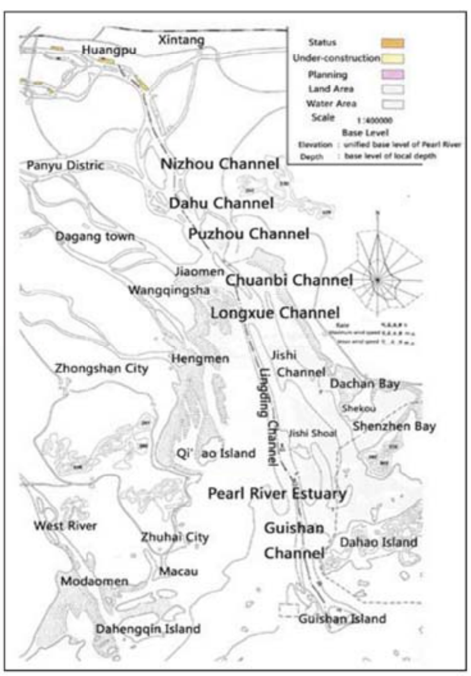


Figure 7 Schematic diagram of Pearl River Estuary.

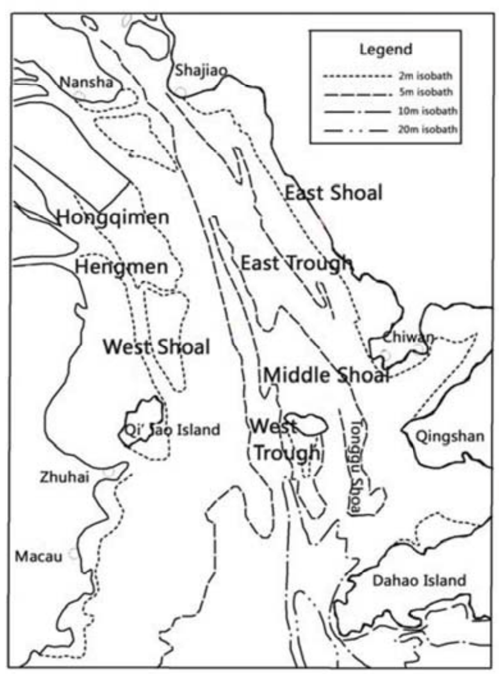


Figure 7 Schematic diagram of Pearl River Estuary. **Figure 8. Schematic diagram of underwater topography in Lingdingyang Bay.**

which play an important role in reducing the wave energy of open seas, regulating the route of tidal current and shaping the local beaches and passages. The tidal current of Lingdingyang Bay belongs to irregular semidiurnal mixed current type, and the mean annual sediment concentration is 0.1~0.2 kg/m^3 for many years. The particle size distribution of bed material is featured by being coarse at the middle beach, fine at the marginal beach, relatively coarse near the bay head and relatively fine around the bay mouth.

The total length of Pearl River Estuary channel is 115 km. Before the 1950s, this channel was in its natural state and the shallowest water depth was about 5 m, used to 5000~7000 DWT vessel navigation.

Through several times' dredging, the water depth of the navigation channel reached 6.9 m in 1959. Since the end of the 1980s, the argument investigation and simulation test studies have been carried out for the route selection of deepwater sea channel over the decades. According to the theory of dynamic geomorphology for river estuary, the interaction among tidal currents, runoff and shelf water with high salinity was used as the basic dynamic structure of Lingdingyang Bay, and then the coastline change of Lingdingyang Bay as well as the trend of tidal current, sediment concentration distribution of muddy water and the location of sediment transport zone were analyzed through remote sensing information. Also, isotope technology was adopted to investigate and detect the density of deposits in the sea channel. A large-scale physical model was established to carry out the experimental study on hydrodynamic and sediment transport in the navigation channel works. A mathematical model of tidal currents and suspended load was established to simulate and forecast the sedimentation and the disposal of dredged material. And finally, the effects of the works were assessed comprehensively. The research findings have provided a valuable reference basis for engineering construction.

In the 1980s and 1990s, the dredging volume in the total section of channel was about 2.6 million m^3 for the purpose of maintaining the water depth of 9.0 m. The sea channel at the Port of Guangzhou has experienced five construction stages over the past ten years, and the navigation standard of the channel was improved from accommodation of 20,000 DWT vessels with the tide in the past to now 100,000 DWT vessels with the tide and 500,000 DWT vessels under all-weather condition. After the first stage of the project was executed, the navigation channel depth was 11.5 m, the annual average deposition thickness in the outer channel was 0.38 m/a, and the volume of siltation was about 2.4 million m^3; and the annual average deposition thickness in the inner channel was 0.18 m/a, and the volume of siltation was about 0.6 million m^3; the annual siltation in the total section of the channel was about 3 million m^3. The navigable channel was deepened by 2.5 m, but the volume of siltation was only increased by 0.4 million m^3. In 2007, a widening and deepening project was conducted at the Port of Guangzhou, specifically at the channel of 46 km long in the south of the navigation channel in the Nansha Port district, so the bottom width of the channel was increased from 160 m to 230 m, and the water depth was increased from 11.5 m to 15.5 m. The topographic detection in 2008 indicates the channel was deepened by 4 m, while the annual siltation volume of the section was still remained at 3 million m^3.

The experience in Pearl River Estuary deepwater channel regulation (Xin 2010a) shows that the deepwater channels can be constructed at some large estuaries in the way of dredging under suitable natural conditions through reasonable route selection and gradual improvement.

COAST PROTECTION AND RECLAMATION

Coast Protection Standards

The state coast protection standards of China have formulated appropriate regulations only from a macro point of view over the years. In the specific implementation process, most of the local coastal protection standards are formulated by the local governments along the coast according to the practical situation and also by referring to relevant standards for coastal engineering. In November 2008, the Ministry of Water Resources directly responsible for the China Central Government issued the *Code for Design of Sea Dike Project* (MWR 2008) which specified the tide defense and flood control standard for sea dike project in view of the type, scale and importance of the protection object (Table 1-1 and Table 1-2).

Table 1-1. Grade of sea dike project

Sea dike construction tide (flood) standard [Return period (year)]	≧100	100~50	50~30	30~20	≤20

Table 1-2. Protection object and Tide (flood) control standard of the sea dike project.

Sea dike grade			1	2	3	4		5
Sea dike construction tide (flood) standard [Return period (year)]			≧200	200~100	100~50	50~30 (50~20)	30~20 (50~20)	20~10
The type & scale of sea dike protection object	City	Importance	Very important city	Important city	Medium-sized city	General city		--
		Population (×10^4)	≧150	150~50	50~20	≤20		--
	Village	Population (×10^4)	--	--	≧150	150~50	50~20	≤20
		Cultivated land protection (ha)	--	--	≧200,000	200,000~ 66,666	66,666~ 20,000	≤20,000
	Industrial & enterprises	Scale	--	Particularly large	Large	Medium		Small
	Sea dike special protection zone	High-tech agriculture (ha)	--	≧66,666	66,666~ 33,333	33,333~ 6,666	6,666~ 3,333	≤3,333
		Crops (ha)	--	≧33,333	33,333~ 20,000	20,000~ 3,333	3,333~666	≤666
		Aquaculture (ha)	--	≧6,666	6,666~3,333	3,333~666	66~133	≤133
		High-tech development zone(Importance)	Very important		Important	Medium		General

Beach Protection Works

Among Chinese coastal provinces all exist deeply-eroded coasts. For example, the strong tidal bore and complicated pattern of coast terrain in Hangzhou Bay cause the siltation of its south coast, and the dangerous situation on the embankment occasionally happens in some cities and towns of Zhejiang Province, located on the north coast, under the action of strong current of tidal bore reaching over 10 m/s. More than 150 years ago, since Yellow River was rechanneled from North Jiangsu Province to flow into the Bohai Sea through Shandong Province, the sediment source was greatly reduced and the coastline of abandoned Yellow River Mouth retreated by about 20 km under action of strong waves.

In the recent years, the seabed topography "equilibrium profile" corresponding to the local dynamics has been ascertained by research (Xu 2001) and an appropriate project has been constructed based on traditional riprap spur dike and beach protection engineering structure of the detached dike, the alongshore structure composed of the pipe piles is also used, so as to reduce the hydrodynamic thrust, protect the beach and even promote the accretion in the eroded region.

In terms of biological beach protection, besides the Chinese traditional plants like reeds and mangroves, spartina aherniflora introduced from Europe between the 1970s and the 1980s has also been applied on a certain scale in Zhejiang, Fujian and other coastal areas of China (Liu et al. 2008).

Sea Dike Engineering Structures

Chinese coastal regions are assaulted by the tropical cyclones and gale of high waves every year. Although Chinese sea dike engineering has a history of several thousand years, the coastal sea dike engineering standard of China was obviously low and the structure was mainly dry masonry till the middle 1990s. In 2009, the data published by the maritime sector showed that the losses caused by oceanic disasters exceeded RMB 10 billion (Liu et al. 2008).

Restricted by the economic conditions, in the southeast coastal areas with storm surges and large typhoon waves (both can reach 3~5 m), the sea dike may be overtopped. Under the condition that wave overtopping is allowed, the structural failure event occasionally happens due to the destruction of dike surface and dike back, thus a series of sea dike structures with different front sloping surface, dike surface and rear sloping surface are adopted, and a lot of dike building experience has been accumulated. The principle of dike building is flexible, thereby bringing the diversity of engineering structure. Figure 9-1 and Figure 9-2 shows some typical sea dike structures.

According to the importance of project, some new modern structures matched with the social economy development are also used in succession. Figure 10-1 and Figure 10-2 shows some typical structures on the soft soil foundation.

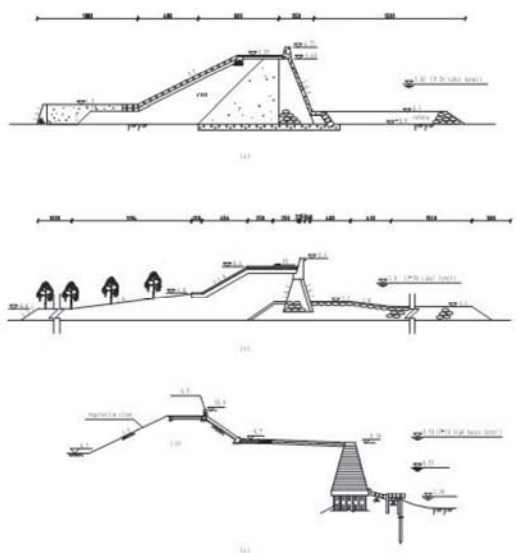


Figure 9-1. Composite structure of sloping type and vertical type.

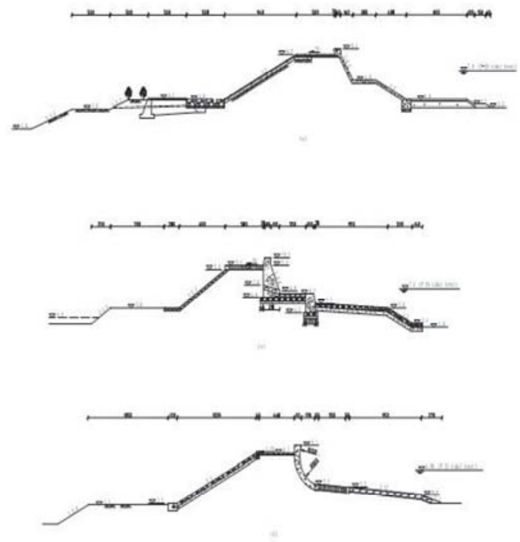


Figure 9-2. Cross section of compound seawall.

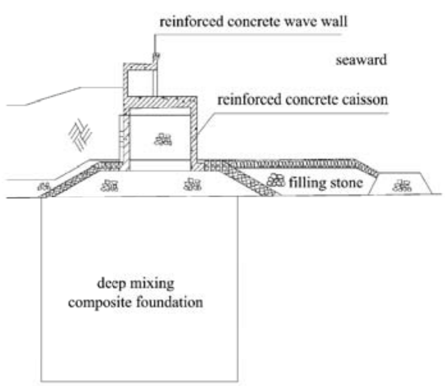


Figure 10-1. Cylindrical caisson + cement deep mixing.

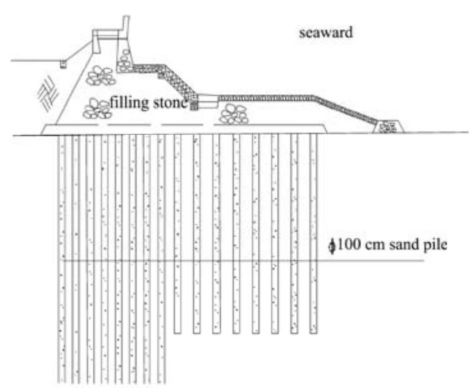


Figure 10-2 .Earth- rockfill dike + Foundation structure treated by large-diameter sand piles.

Reclamation Works

In order to meet the economic development requirements of land use of industries, urban expansion and agriculture in coastal area, the reclamation projects in China have been made great achievements over the last decade.

According to the provisions of guidelines for estuary flood control promulgated by the government, the sea reclamation works is executed in combination with the construction of urban land and access channel in the estuary area and the construction of estuary delta port in an orderly way. Qingcaosha reservoir (Lu Z.M. et al. 2009) giving priority to the storage of fresh water is constructed at the Yangtze Estuary, which provides another important water source for the water supply of Shanghai City. Qingcaosha reservoir covers a total area of almost 70 km^2, with a total designed reservoir capacity of 524 million m^3, or an effective reservoir capacity of 435 million m^3 and a daily water supply scale of 7.19 million m^3 (Figure 11). In coordination with the construction of the Yangtze Estuary deepwater channel, the local government carries out the planned sea reclamation in the Pearl River Estuary (Xin 2010a). The isles connection project mainly concerned with the construction of the Yangtze Estuary deepwater port is implemented at the Oujiang Estuary, Zhejiang Province (Figure 12) (Xu Q. et al. 2009). In Caofeidian, Hebei Province at the bay of Bohai Sea, in order to meet the needs of iron & steel and petroleum industry development, the sea beach with an area of over 100km^2 is successively reclaimed, thereby making contributions to the major state projects like the relocation of Shougang Group.

Figure 11. Qingcaosha reservoir project at the Yangtze Estuary.

Figure 12. Isles connection project at the Oujiang Estuary.

The reclamation works is combined with wetland, maintenance natural reserves and animals in Jiangsu Province, and the land with an area of 67,000 hectares has been reclaimed in the recent ten years, partly becoming the grain production base for Shanghai. Zhejiang Province pays attention to maintaining the dynamic equilibrium of beach and wetland, and adopts an appropriate siltation promotion method according to the evolution law of the regional shoal and wetland, implements "one promotion one reclamation" or "two promotion one reclamation", and spares no efforts to find the equilibrium point between beach reclamation and wetland protection that they complement each other in order to realize the optimal coordination between human and nature.

HARBOR WORKS

Overview

The development of the port engineering along the coast of China has roughly experienced several stages, construction recovery period from 1950s to 1960s, the stage of port construction from 1973 to 1978 and the one of port construction from 1980s to the early 1990s. Since the 1990s, a number of large-scale specialized berths have been constructed and a number of sea access channels have been regulated, so the coastal ports develop faster. Currently, there are more than 150 coastal ports in China (including the ports in the lower reaches than the location of Nanjing along the Yangtze River) (Figure 13). In 2008, the ports in China completed a total cargo throughput of 7,022 billion tons, remaining No. 1 in the world for six consecutive years. The capacity is 700 times as much as that of 1949 (MOC 2006).

According to the status and characteristics of the economic development in different areas, and the current situation of ports inside the area and the transport relationship among the ports, the coastal ports of China can be divided into five port group systems, i.e., around the Bohai Sea area, in Yangtze River Delta, Southeast coast, Pearl River Delta and southwest coast. The port group system around the Bohai Sea area is composed of port groups along the coasts of Liaoning, Tianjin, Hebei and Shandong, while the port group along the coast of Liaoning Province mainly consists of the Port of Dalian and Port of Yingkou, and also the port of Dandong and the Port of Jinzhou; The port group along the coasts of Tianjin and Hebei is mainly the northern international shipping center in Tianjin and the Port of Qinghuangdao, including Port of Tangshan and Port of Huanghua and so on; The port group along the coast of Shandong mainly includes the ports of Qingdao, Yantai and Rizhao as well as Weihai. The port group system in the Yangtze River Delta, based on Shanghai International Shipping Center, mainly includes the ports of Shanghai, Ningbo and Lianyungang and gives full play to the ports along the coasts of Zhoushan, Wenzhou, Nanjing, Zhenjiang, Nantong and Suzhou and the other ports at the lower reaches of Yangtze River. The port group system in the southeast coastal area is mainly the Port of Xiamen and the Port of Fuzhou, including the ports of Quanzhou, Putian and Zhangzhou; the port group in the Pearl River Delta area, consisting of the ports in Eastern Guangdong and the Pearl River Delta, takes the advantage of Hong Kong in its economy, trade, finance, information and position of international shipping center so as to mainly develop the ports of Guangzhou, Shenzhen, Zhuhai and Shantou and accordingly to develop the ports of Shanwei, Huizhou, Humen, Maoming and Yanjiang while consolidating the position of Hong Kong as an International Shipping Center. The port group system in southwest coastal area, composed of the ports in Western Guangdong, along the coast of

Guangxi and in Hainan Province, mainly develops the ports of Zhanjiang, Fangcheng and Haikou and accordingly develops the ports of Beihai, Qinzhou, Yangpu, Basuo and Sanya, etc.

Figure 13. Distribution diagram of coastal ports in Mainland China.

Construction of the Main Ports

(1) Construction of the port group around the Bohai Sea Area.

a. Construction of Dalian Port.

The Port of Dalian, the International Shipping Center of Northeast Asia, is a deep and broad port, free of freezing in winter. The tide belongs to the semi-diurnal tide mixed type. On the coastline of nearly a few kilometers from Dayao Bay to Tiger Beach, there is a port at an interval of 4 km on average. It is a "gold coast" with the highest density of port distribution in China (Figure 14-1). Currently, there are more than 110 berths, including 40 berths for ships above 10,000 DWT, 8 navigation channels in the port district and 9 breakwaters. Recently, crude oil terminal and ore terminal for ships of 300,000 DWT have been constructed (Figure 14-2), and a new crude oil terminal with a water depth of -27 m accommodate supertankers up to 400,000 DWT. After 2006, another new port district that is bigger than the old one is under-construction in Changxing Island and will be completed in 2015.

Figure 14-1. Aerial view of Dalian Port .

Figure 14-2. Terminal for 300,000 DWT ore carriers in Dalian Port.

b. Caofeidian Port district in the Port of Tangshan.

Caofeidian is an ancient sand island, 18 km off the shore in Bohai Bay. It was discovered 1985 in a general survey of the coastal areas that the island was a rare port site along China's coast which could accommodate ocean liners of above 250,000 DWT. At the beginning of 2006, the construction of Caofeidian Industrial Zone in Tangshan was listed in the national "Eleventh Five-year" development plan. The overall development and construction of Caofeidian is to be carried out in a short-term and a long-term scheme. The major projects include: by taking advantage of the natural port site of Caofeidian, 200 km2 of land will be reclaimed from the sea, to construct 4 ore terminals for ore carrier up to 250,000 DWT, 2 crude oil terminals for tankers up to 300,000 DWT, 16 coal terminals for coal carriers from 50,000 DWT to 100,000 DWT and 1 LNG terminal for LNG carrier up to 100,000 DWT. Caofeidian Port district in the Port of Tangshan becomes one of the fastest growing port districts in the recent ten years in China (Figure 15).

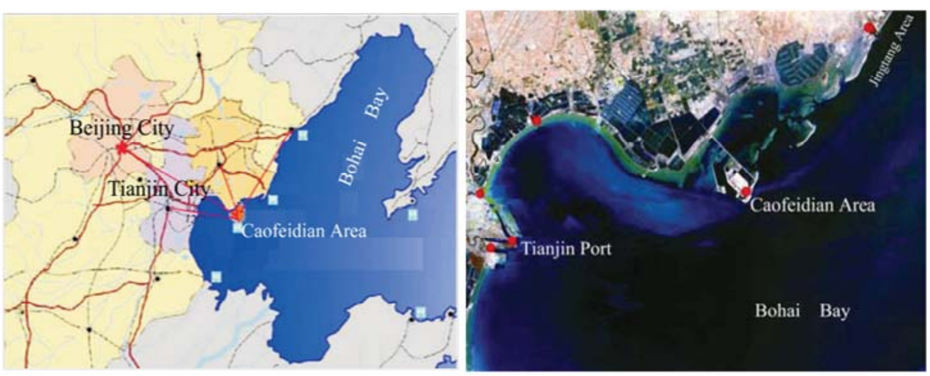


Figure 15. Location of Caofeidian Port.

c. Tianjin Port.

The Port of Tianjin, the largest artificial port in China, is located at the gathering point of Bohai-Rim Economic Circle and the maritime portal of Beijing and Tianjin. The Port of Tianjin currently covers a water and land area of nearly 260 km^2, in which the land area is 72 km^2. The main channel of this port is 35 km long and -19.5 m deep, and 250,000DWT vessels can freely enter and leave the port and 300,000DWT vessels can enter and leave the port with the tide. There are totally 139 berths of various grades, with a total berth length of 27,700 m, including 76 berths for vessels above 10,000 DWT (Figure 16). According to the planning, the annual throughput of the Port of Tianjin will reach 400 million, 550 million and 700 million tons in 2010, 2015 and 2020 respectively.

d. Qingdao Port.

The Port of Qingdao, located in Jiaozhou Bay at the south shore of Shandong Peninsula, is deep and broad and navigable all year round. With a small mouth and a large belly, this port is an excellent port famous in China (Figure 17) with a history of 117 years. It is mainly comprised of Dagang, Zhonggang and Huangdao port districts, and possesses 15 wharfs and 72 berths, including 6 berths of 50,000 DWT, 6 berths of 100,000 DWT and 2 berths of 300,000 DWT. It is mainly engaged in the loading and unloading service of containers, coal, crude oil, iron ores and grain as well as the international and domestic passenger service. It has trade contacts with more than 450 ports in over 130 countries and regions across the world. In 2008, the annual throughput of containers in the Port of Qingdao broke through 10 million TEU, becoming one of the world's top ten largest ports.

Figure 16. Tianjin Port.

Figure 17. Phase III container terminal in the Qianwan Port District of Qingdao Port.

(2) Construction of port group in the Yangtze River Delta.

a. Yangshan Port district of International Shipping Center of Shanghai.

Yangshan Port district of Shanghai International Shipping Center, located at the Qiqu Archipelago outside Hangzhou Bay, is about 30 km away from Shanghai in the southeast and only 45 sea miles away from the international channel line. It is a natural port site closest to Shanghai with a water depth of 15 m. The overall planning (Cheng 2005) for the Yangshan deepwater port district is to create a south port district and a north port district based on the large and small Yangshan Island chain in four construction stages (Figure 18). Till 2020, in the north port district (at one side of the small Yangshan Island chain), a deepwater shoreline of about 11 km will be formed and more than 30 deepwater berths constructed, and the annual handling capacity of containers in the built Yangshan Port district of International Shipping Center can reach 15 million TEU.

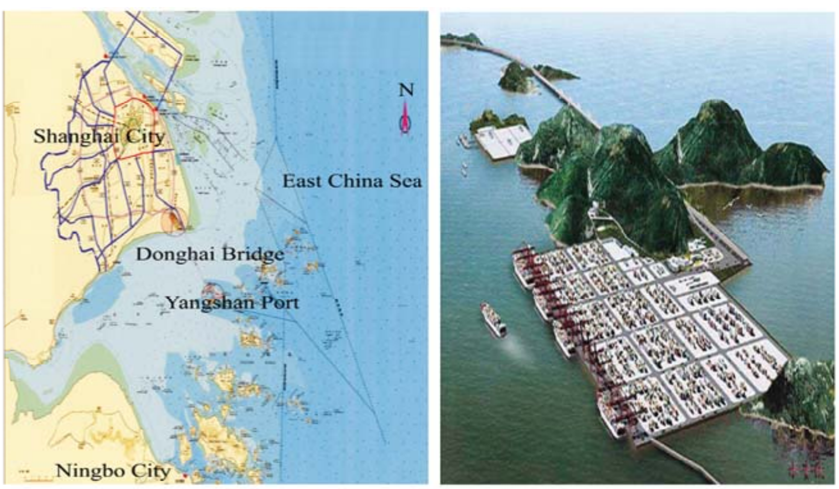


Figure 18. Yangshan Port of International Shipping Center.

The Yangshan deepwater port works set an important precedent for constructing the large-scale container port district in the sea area with high current velocity and high sediment concentration and on the offshore island 30km away from the mainland in the port construction history of China and even of the world. The engineering construction has solved many key technological problems in the engineering design, scientific research, construction and survey of the ports in the deep and open water area against the open sea, and enriched the port engineering technology, formed the packaged technology for the design and construction of large-scale port works on the island in the deep and open water area against the open sea and fully improved China's technical capability in port construction. Since the commencement of the Yangshan deepwater port works in June 2002, Phase I and II small Yangshan port districts and middle port district have been successively constructed and the fork channels have been blocked. Nine large-scale container berths with berth length of 3 km in the phase I project and phase II project are successively put into operation.

b. The Construction of Ningbo-Zhoushan Port.

The Port of Ningbo, located at the east coast of Zhejiang Province, includes five port districts, i.e. Beilun, Ningbo, Zhenhai, Daxie and Chuanshan. It is an important port for foreign trade and a transshipment hub for maritime transport in Chinese history, as well as one of the four largest international deepwater transshipment ports under key development and construction of Mainland China (Figure 19). Zhoushan is an emerging island port tourist city in China, with remarkable advantage in its location and unique natural resources of "fishery, port and scenery". Ningbo-Zhoushan Port is a combination of the Port of Ningbo and the Port of Zhoushan, and thereby it is a port city extending from coast to ocean, connecting the island and the mainland, closely combining the development of characteristic island economy with the fairly complete infrastructure network of the mainland. The port also combines China's best deepwater shoreline resources with the vast area of land which embodies a far-reaching significance in further developing the marine resources of Zhoushan and promoting the economic development of Zhejiang Province, of Yangtze River Delta and even of China. The overall planning for Ningbo-Zhoushan Port divides itself into 19 port districts. Cargo handling capacity of Ningbo-Zhoushan Port in Zhejiang was 570 million tons in 2009 and it will reach 840 million tons in 2020.The container throughput will reach 26 million TEU and the passenger throughput will reach 4 million person-time.

Figure 19. Location of Ningbo-Zhoushan Port.

(3) The Construction of Guangzhou Port.

The Port of Guangzhou, located at the Pearl River Estuary and the heartland of the Pearl River Delta with the most energetic export-oriented economy in China, borders on the South China Sea and adjoins Hong Kong and Macau (Figure 20). The port is a comprehensive main hub port in South China. The Port of Guangzhou currently has 50 berths for vessels over 10,000 DWT, 13 handling floats for vessels over 10,000 DWT and 23 handling anchorages for vessels 10,000 DWT (the maximum mooring capability is for the vessel of 300,000 DWT). From 2005 to 2010, about 40 deepwater berths were constructed in the Port of Guangzhou and the newly increased handling capacity reaches nearly 70 million tons and more than 6 million TEU. It is predicted that the cargo handling capacity of the Port of Guangzhou will reach 400 million tons and the container throughput will reach 14 million TEU by the end of 2010, and then it will become a trunk port with a significant influence over container transport in the world, and a modern comprehensive hub port, mainly for the transshipment of goods like energy sources and raw materials.

Figure 20. Location of the Guangzhou Port.

Main technical progress

Technical progress of port construction along the silty sand coast. The silty sand coast belongs to a transitional coast between the muddy coast and the sandy coast, with a gentle slope, generally 1:500~1:10000. The grain size D_{50} of the silt is 0.031~0.125 mm. The characteristics of its movement are mainly as follows: easy to suspend and deposit under competent velocity, so sediment short term deposition in the windy days is the mere critical problem in port construction after the channel is excavated. Since the early 1990s, China has carried out a series of exploratory research on such type of coasts. Taking comprehensive research measures like theoretical analysis, physical model, mathematical model, analysis of remote sensing pictures and study on sediment property, an in-depth and systematic research (Dou 2009) was conducted on the sediment problems of such silty sand coasts such as the ports of Huanghua, Caofeidian, Dongying, Weifang and Rudong based on the analysis of field observational data, dynamic conditions and sediment environment. In the end, the sediment movement mechanism of silty sand coasts has basically figured out. The adoption proposal of twin jetties extending outside the wave breaker zone has successfully solved the short term deposition problem in the port construction of silty sand coasts.

The Port of Huanghua in the phase I project is surrounded by the north and south breakwaters. Due to limited expenditure, the head of jetties is located at the water depth of -2.5 m, and the design water depth of the navigation channel is -11.5 m, with bottom width of 140m and channel length of 27.5 km and an azimuth angle of 55°~235°. In 1997, the Port of Huanghua began to be constructed on a full scale. The sediment short term deposition of the channel outside the Port of Huanghua not only had great intensity and a wide distribution range of strong deposition area, but also had poor dredgeability for the bed deposits at a comparatively long section, so it was difficult to ensure the normal navigation of vessels by merely relying on the single measure of dredging. The regulation project has been implemented since May, 2005 (Yang 2009). In the regulation project, the extending north and south jetties are 10.5 km long, and the head of jetties extends to about -6.0 m and the navigation channel depth is over 13.0m (Figure 21-1 and Figure 21-2). After the completion of regulation project, the condition of bed material in the sheltered section has been greatly changed, and the navigation condition has been obviously improved.

Figure 21-1. Layout plan of the phase I project of the Port of Huanghua.

Figure 21-2. Layout plan of regulation project for the channel outside the Port of Huanghua.

Technical progress in port construction on radial sandbank. The outline of Yellow Sea composed of Korean Peninsula, Shandong Peninsula and Jiangsu Coastal Zone forms the condition that the convergence of tidal waves in the eastern sea area outside the coast Jiangsu Province. The mobile standing tidal waves resulting from the convergence of tidal waves provided necessary dynamic environment for the formation of underwater deposits at the ancient Yangtze Estuary; and now, in the modern coast period, it also provides necessary conditions for the formation and maintenance of more than 70 radial sand ridges group. The property of standing wave of the tide in the sand ridge zone, large tide range and radial tidal current field creates and maintains the structural form of the ridges group with alternated broad beach and deep channel on the section (Figure 22).

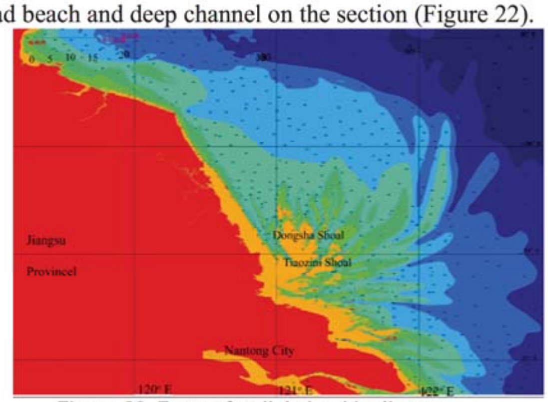


Figure 22. Form of radial shoal in Jiangsu.

Over the years, the radial sandbank has been considered a restricted zone for port construction, and the coastline of nearly 400km becomes a blank zone where no port is constructed, thereby seriously restricting the development of coastal areas of Jiangsu Province. Since the 1990s, systematic field observation, theoretical analysis, physical model and mathematical model research have been carried out in this area (Lu P.D., 2009), contributing to an in-depth recognition of the evolution law of radial sandbank. And a significant progress has thus been made in trial construction, the Dafeng Port and an artificial island on Xitaiyang sandbank of Yangkou Port were constructed. The research indicates that Xitaiyang sandbank is a beach connected with coast and composed of fine sand and silty sand, possessing strong activity in the surface layer. The complex dynamic environment where the tidal inlets are connected to one another and the composition of substances with strong movability causes that its evolvement trend is quite active, but the main part of the beach is basically stable. The general pattern of the radial sand ridges is correspondent with the characteristics of convergent and divergent current field, and the deep tidal inlets are stable and channels has existed for a long time. All these indicate that there is a prospect for development and utilization. Wharfs with berths for ships of 50,000 DWT to 300,000 DWT can be constructed in this place. Construction officially started in 2003, concerning other key projects: sea-crossing bridge, 10,000DWT berths and LNG project. Navigation channel was preliminarily opened on October 28, 2008.

Dafeng Port is another successful example for port construction on the radial sandbank. By taking advantage of the sand ridge's barrier action and the favorable water depth of deep inlet channel between the sand ridges, currently two berths for ships of 10,000 DWT are constructed without destroying the original hydrodynamic characteristics by combining the mole type with the permeable structure.

New wharf structures.

(1) Perforated cylindrical caisson structure.

The main part of maritime structure for the ore and crude oil terminals at the Port of Dalian adopts the perforated gravity pier structure. The conventional cylindrical caisson structure appeared a larger wave run-up and larger wave forces under the design wave action. In order to achieve the effect of wave reduction and dissipation and effectively reduce the wave run-up, the perforated cylindrical caisson scheme is proposed, and a physical model test is conducted for verification, based on theoretical analysis and demonstration of its action mechanism (Li 2007). The caisson wall is perforated at a rate of 20% within the range of 7.0 m at the top of the caisson, so the deck elevation of structures is reduced by 2.5~3.0 m, and the wave force, acting on the terminal's pier foundation, is reduced by 20%~30%.

(2) The development of new structure of covered type sheet pile wharf.

According to statistics available, the sheet-pile wharfs constructed in Mainland China have about 300 berths, among which more than 200 are used for the small and medium-sized wharfs, accounting for over 85% of the total number, and the largest wharf is only below 35,000DWT. Some difficulties have arisen due to the structural weakness of sheet-pile wharfs, mainly because the bending resistance of the sheet-pile section is hard to satisfy the requirement for the sharply increased bending moment of the deepwater wharf. In 2000, there was a plan for Jingtang Port District in the Tangshan Port for deepening and transformed the two berths of the sheet pile wharf for vessel of 20,000DWT into the berths for vessel of 50,000 DWT, and as a result, a semi-covered type sheet-pile wharf structure (Figure 23-1) was successfully developed. Later on, a schematic design of 70,000DWT and 100,000DWT berths and the new structural form of fully covered type sheet-pile wharf (Figure 23-2) was developed in 2003 (CCCC First Harbor Consultants Co. Ltd. 2007), in order to build a reasonable structural form of deepwater and large tonnage berths for vessels over 100,000DWT under the condition of dug-in port basin. This project was launched in 2004, and currently the berth has been completed.

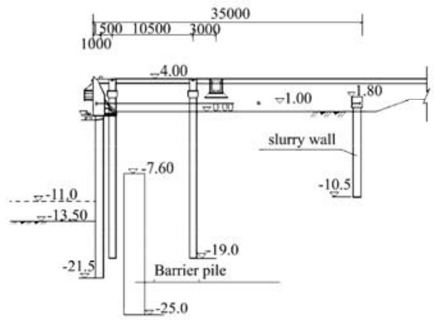


Figure 23-1. Semi-covered sheet-pile wharf structure diagram.

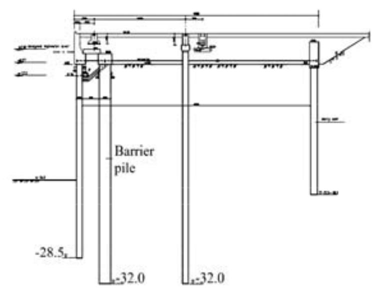


Figure 23-2. Fully covered sheet-pile wharf structure diagram.

The following is the advantages of the covered sheet pile wharf structure: (a) The pressure on the front wall is effectively reduced, which creates the condition for increasing the front water depth of the sheet-pile wharf; (b) The original wharf surface and other structures do not have to be removed, which saves cost, shortens construction period and reduces the influence on production to the maximum; (c) As the water depth of the wharf is deepened and reconstructed, its frontline neither has to move forward, nor has to occupy the port basin or affect the effective length of the suspension arm of gantry crane; (d) The construction is executed all on land, so it is not affected by weather, wave and tide, and the ships still can accommodate alongside the wharf during the construction period. (e) More construction cost is saved than other feasible schemes.

New breakwater structures.

(1) New structure of comb type breakwater.

The maximum flow velocity at the mouth of Dayao Bay was 0.57 m/s before the construction of breakwater. Based on the traditional vertical-wall solid type, the flow velocity at the north and south port entrances will reach 1.3 m/s and 1.52 m/s respectively after the whole breakwater works is completed. The current flow velocity at the port entrance is required not to exceed 0.77 m/s during the port operation, but the breakwater built in a traditional structure cannot guarantee navigation safety, and at the same time the deepwater channel in the port district will cause the change of wave conditions around the breakwater, and the design wave height will be increased by 50%. The red soft secondary mild clay layer is under the bearing layer of the island breakwater, so a large amount of excavation and filling is required if the traditional structure is adopted. These factors lead to the substantial increase of construction costs.

The comb type breakwater is a comb type upright breakwater formed on the plane by the caisson flange plates replacing the square caissons taken out from the traditional square caisson breakwater in an appropriate proportion (See Figure 24-1). The flange plate may be only the half of the whole height. The test proves that the total horizontal force of waves can be reduced by 27% to 38% at the design high water level, and the total horizontal wave load can be reduced by 22% to 36% at the extreme high water level (See Figure 24-2). The wave-transmission through the flange plate is not large and the transmitted wave height is less than 0.3m for the waves of two years return period (China Communications Water Transportation Planning and Design Institute Co. Ltd. 2007).

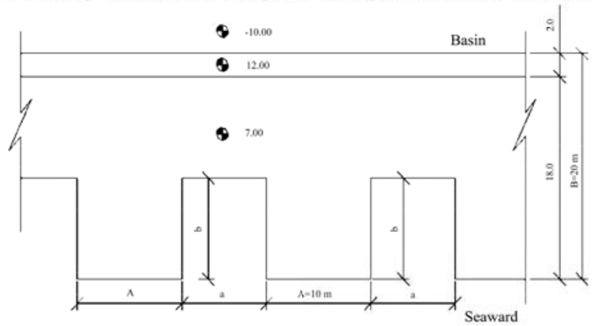


Figure 24-1. Plan of comb type structure.

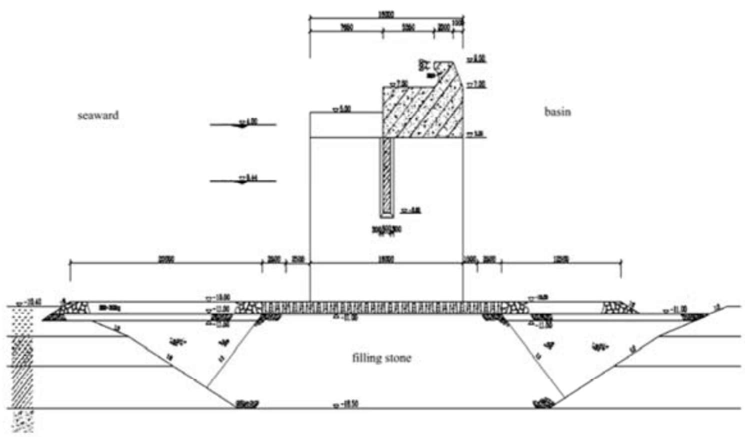


Figure 24-2. Cross section view of offshore breakwater of Dayao Bay in Dalian Port.

(2) Breakwater with Penetrated Caisson Type Substructure.

Breakwater with penetrated caisson type substructure is applicable to the situations where there is a lack of sand and stone materials, the physical and mechanical indexes of the subsoil are poor and the water depth is quite large. The lower part of the breakwater is a penetrated caisson type structure, while its upper part is a wave screening structure (Figure 25). This breakwater structure is light in weight, and easy to satisfy the stability requirement. It can be prefabricated as a whole and pneumatically floated during towage. Moreover, this structure can be moved and reused, with low construction cost, convenient field installation and high operation speed. The structure could also be applicable to the soft soil foundation.

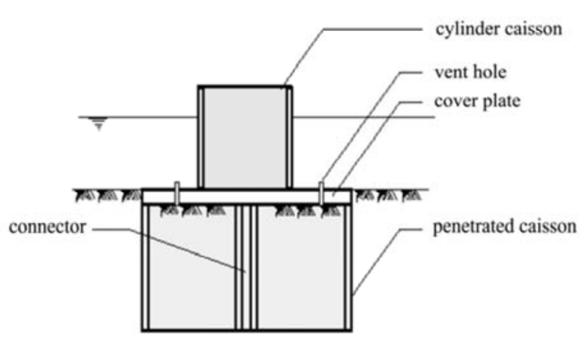


Figure 25. Cross section of the breakwater with penetrated caisson type substructure.

The pilot project of breakwater with penetrated caisson type substructure is located at the south end of the east outer bank of North Grand Breakwater in the Port of Tianjin, and the subsoil above -25.0 m is mainly divided into three layers: the first layer is mud and muddy clay, distributed within the range of 0~11.5 m on the surface layer; the second layer is silty clay and silt, distributed within the range of 10~16 m below the surface layer; and the third layer is silt and silty sand. The settlement of the breakwater with penetrated caisson type substructure is far smaller than the traditional rubble mound breakwater and other compound breakwater structures (Tianjin Port (Group) Co. Ltd. 2007).

(3) Multi-layer perforated caisson breakwater structure.

In the area of deep waters and large waves, the breakwater can also be designed as perforated caisson type structure. Figure 26 is the typical cross section of the breakwater with 5 layers of wave absorbing plates at Dalian Chemical Production Terminal (Li 2007).

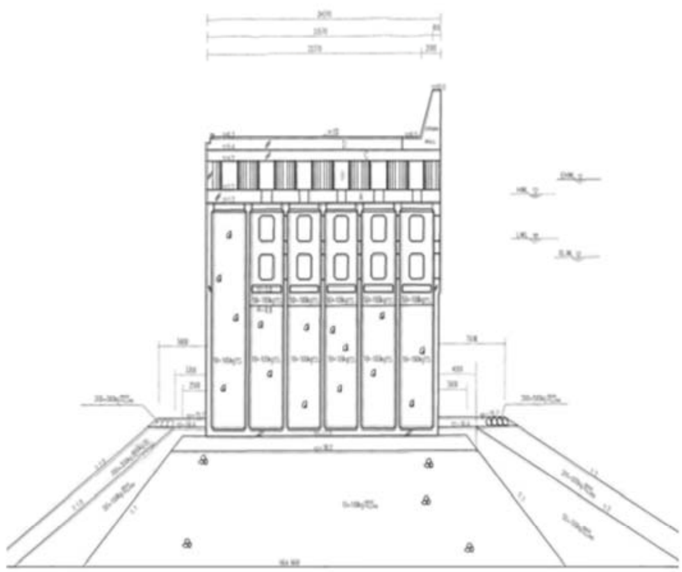


Figure 26. Cross section of the breakwater at Dalian Chemical Production Terminal.

SEA-CROSSING BRIDGE WORKS

Su-Tong Bridge at the Yangtze River Estuary

Su-Tong Bridge is the largest estuary bridge in China, with the total length of 32.4 km and maximum main span of 1,088 m, and it is also the cable stayed bridge with largest-span in the world today. The design life of bridge is 100 years. The bridge location is 108km away from the Yangtze River entrance, and the river surface is 6km wide. The water depth at the main bridge pier is over 30 m, and there are two tides each day with a tidal range of 2~4 m. The flow velocity at the bridge site is over 2.0 m/s all year round, and the maximum flow velocity is 4.47m/s; the buried depth of bedrock reaches 300 m, and the riverbed is liable to be scoured by water flow. The research indicates (You et al. 2009) that the local scour depth of the bridge pier can reach 20 to 30 m if there is no protection, and the shape of scour pits is complex; there is a high navigation density and a large vessel tonnage in the bridge zone, and over 2,300 vessels pass through the bridge zone per day on average, but up to almost 5,000 vessels at the peak time. Therefore, there was acute contradiction between shipping and construction safety. In order to ensure the structural safety in the construction period and operation period, the riverbed needs to be subject to more permanent scour protection. The main pier foundation of Su-Tong Bridge is composed of 131 pile groups with a length of about 120 m and a diameter ranging from 2.5 m to 2.8 m, while the platform is 114 m long and 48 m wide. It is one of the largest and deepest pile group foundations in the world. The bridge has completed and opened to traffic in 2008.

Hangzhou Bay Bridge

Hangzhou Bay is located at south side of Yangtze Estuary, both entrances are adjoining, it is a bay with the largest tidal range along China's coast, and the maximum tidal range once reached 8.93m in history.

Hangzhou Bay Bridge has a total length of 35.5 km, in which the length at the maritime section is 32 km, and the design life of bridge is 100 years. The water area at the project site is characterized by adverse natural conditions, broad sea area, appeared many typhoons, large tidal range, rip current, disordered flow direction, high wave, deep scour depth and thick soft ground and shallow-buried natural gas in some sections. Most of the maritime engineering is under infralittoral operation resulting in poor construction conditions. The maritime engineering is faced with the challenges of many key construction technologies (Lu et al. 2006), such like overall prefabrication, transport and erection of large-scale box girders at the maritime rip current area and high pier area, long-distance transport and erection of large-scale box girders on the girders in the wide intertidal zone, and design and corrosion prevention of extra-long spiral steel pipe piles and construction of submerged piles. In terms of measurement control, because the bridge is super long, the problem on structural measurement deformation caused by the earth's curvature effect is very prominent; due to the restriction of the marine environment, the traditional measurement means cannot satisfy the requirement for construction accuracy and construction progress; and the key technical problem which restricts the construction period of the whole bridge is to realize the rapid and highly-efficient measurement and construction by means of GPS technology. The main project of the bridge was launched in 2003, and completed and opened to traffic in 2008.

Island-connecting Bridge of Zhoushan Islands

Zhoushan is a rising island port tourist city in China, scattered with many islands and reefs. There are more than 1,000 large and small islands, approximately accounting for 20% of the total islands in China and covering a maritime area of 22,000 km^2 and a continental area of 1,371 km^2, in which nearly 60 islands have an area of over 1 km^2, accounting for 96.9% of the total area of Zhoushan Islands. The whole island group is orderly arranged from north to east. For a long time, separated by a strip of water, Zhoushan Islands is isolated and its economy is greatly restricted. In 1999, the island- connecting bridge officially commenced, starting from Zhoushan Islands by way of Lidiao Island, Fuchi Island, Cezi Island and Jintang Island, with a total length of about 50 km (Figure 27). In 2009, it was officially open to traffic, then Zhoushan blends into the economic circle of Yangtze River Delta more closely and becomes a peninsula connected with the mainland and a port city for the mainland extending to the ocean. The construction of the bridge realized the connection between islands and the mainland, and closely combined China's best deepwater coastal resources with the vast land. It is of far-reaching significance in further developing the marine resources of Zhoushan and promoting the economic development of Zhejiang Province, Yangtze River Delta and even China.

Figure 27. Zhoushan Islands and the island-connecting bridge works.

Hong Kong-Zhuhai-Macau Sea-crossing Bridge under Construction

Hong Kong-Zhuhai-Macau Bridge, extending across Lingdingyang of Pearl River estuary, connects Hong Kong, Zhuhai and Macau (Figure 28), with a full length of 50 km. The main works including "Bridge and Tunnel in the sea" possess 35.578 km long, of which the bridge is about 29 km, the tunnel is 6 km long, the east and west artificial islands of the Bridge and Tunnel is totally 1.25 km. it is not only complicated in the conditions of wind wave, tidal currents, sediment transport and salt-fresh water mixing, but also involved in many technical difficulties such as water conservation, water transportation, ecology and environment. The flood and tide safety and 300,000 tons oil tanker two-way shipping are a premise that the bridge construction. With a design service life of 120 years, Hong Kong-Zhuhai-Macau Bridge can withstand a wind speed of 51 m/s and earthquake of 8.0 magnitude. The pier is designed on an impact resistance of 30,000 ton, and the anti-collision pier is built on an impact resistance of 300,000 ton. In addition, there will be landscape construction, a white dolphin viewing area and a marine viewing platform. Hong Kong-Zhuhai-Macau Bridge is one of the most technologically complex and the highest standard of engineering in the history of China Transportation Construction (Xin et al. 2010b). The bridge is planned to be constructed within a period of 6 years. The main structure is constructed at 2010 and estimated to be completed during 2015-2016.

Figure 28. Location of Hong Kong-Zhuhai-Macau Bridge.

PERSPECTIVE

Perfecting the Coastal Dynamic Monitoring System of Mainland China

After several decades' construction and development, Mainland China has also preliminarily formed a dynamic observation system of coastal. For some large and middle-sized coastal engineering projects, the government also explicitly requires field observation for strengthening scientific verification. To find out the current coast and ocean situations including coastal engineering along the coast of China, and to plan and optimize the maritime development layout, China has carried out in 2007, a special project of "Coastal and offshore Comprehensive investigation and Evaluation of China", attempting to construct a foundation framework for China's offshore "digital ocean" information. However, in general, the marine observation means is mainly lied on shore-based stations. They are insufficient in amount, weak in offshore observation capacity and low in spatial coverage and the distribution fails to meet the demand of scientific research; in addition, the data on long-term and continuous observation is too limited to meet the requirements of multidisciplinary synchronous observation; the observation technology is relatively outdated, thus there is a large gap between China and the developed marine countries, which restrains the development of scientific research on coastal engineering. The important work in the future period is to build an efficient and stable three-dimensional marine observation network with a wide coverage by using shore-based stations, radar, buoy, subsurface buoy, offshore platform, satellite remote sensing and other observation means so as to improve the marine observation technology level, and to establish an open and shared digital management application platform so as to provide a basis for decision-making concerning the prevention and alleviation of marine disasters.

The Task of Coastal Protection Works will Become More Arduous

The water and soil conservation and the construction of hydraulic engineering at the upper reaches of rivers pouring into the sea caused that the total amount of sediment flowing into the sea is sharply reduce. After the completion of the Three Gorges Project on Yangtze River in China, the sediment flowing into the sea at the Yangtze River estuary has reduced by more than one half; in the estuary delta region of Yellow River, the second largest river in China, some areas have been scoured due to scarcity of water, water intake of the upper reaches and the construction of Xiaolangdi Key Water

Control Project. These also occurred to some other river estuaries. In the past, the coastal sandbank in estuary areas of China were mainly of the siltation-rise type, with fast epeirogenic speed, but this phenomenon has obviously changed now. The increasing number of structures in coastal engineering separates the transport route of some coastwise sediment and causes also the scour of some coastlines which were kept balanced.

The original coast protection standard of China is relatively low. Along with the rapid development of coastal economy and the urbanization of original coastal villages or small towns, the corresponding coast protection standard must adapt to its protection range and importance; the reclamation of coastal beaches makes the front sea dike shift out, the water depth under the dike toe is increased and the hydrodynamic action appears enhanced also. The statistical data shows that the sea level in the coastal zones of China rises for nearly 10 cm in the recent thirty years.

These factors require intensifying efforts on the coastal protection works (like sea dike, and tidal sluice gate, etc.) of China for the purpose of integrating disaster prevention and reduction.

There will be More and More Development Demands for Coastal Engineering Technology in the Severe Natural Environment

Large-size ships require an increasing number of deepwater berths, but the nearshore water depth is not able to meet this requirement. It is expected in the next few years that Mainland of China will build a significant number of wharfs incorporating the berths which can accommodate the vessels of 200,000DWT to 300,000DWT and even 500,000DWT, that the frontline of wharfs will move towards the deep water area, and that the reliability research on port engineering structure under the extreme conditions like action of storm tide and typhoon surge as well as corresponding standard formulation work will be carried out in succession.

The coastlines with relatively favorable natural conditions have been almost developed and utilized, and the coastlines with relatively complicated natural conditions like silty sand beach and radial sandbank are also explored more developed and utilized. In order to meet the needs of national economic development, the coastal zones with strong sediment movement at the broad beaches and swales and also the construction projects with good condition of front water depth but complicated onshore conditions will increase the difficulty of the coastal engineering technology.

The sea-crossing bridge and tunnel project in the severe environment will also become another hot issue of China's recent coastal engineering. For example, the proposed Qiongzhou Strait sea-crossing bridge works will encounter many adverse factors such as deep water, strong wind, high wave, complex geologic structure, high navigation requirement and environmental sensitivity, so there are considerable technical difficulties in bridge building. Qiongzhou Strait is one of the three largest straits in China. It is located between Leizhou Peninsula in Guangdong Province and Hainan Island, with a length of about 80 km and a width of 20 to 40 km, an average water depth of the strait is about 44 m and the maximum depth of 120 m; what's more, the bridge site must avoid the coral reefs in the core area of the National Nature Reserves.

Coastal Hydrophilic Projects will Grow Rapidly

A series of economic development zones have been built along China's coast, and the increase of coastal cities requires the construction of more recreational facilities and hydrophilic projects.

The Coordination of Marine Ecology and Coastal Engineering Requires to Strengthen the Research on Costal Engineering Management

The coordination of costal engineering construction and marine environment demands further consolidation of the development of subjects regarding coastal engineering management, like saline water intrusion due to sand mining and channel dredging at the estuarine area; the influence on the nearshore marine ecology by large-scale reclamation works; and the influence on water quality by the water intake and drainage works of power plants and steel plants along the coast and the aquaculture breeding project.

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