CHAPTER 175

Composite Type Breakwater at Taichung Harbor, R.O.C.

Chung-Chuang Wu*

The composite type breakwater used in Taichung Harbor contributes economical cross section and better consideration of drifting sand control. Also, with the plan of making caissons on the sand beach and installing caissons by using an unprecedented "Island" method, it shorten the construction period of breakwater significantly.

1 Introduction

The government of Rep. of China decided to build a new port in the central part of the west coast of Taiwan, known as Taichung Harbor, about two decades ago. Its purpose was to cope with the problems caused from the rapid economic growth; such as to balance the population distribution, to alleviate inland traffic congestions and to release the burdens of other ports.

Shallow beach and straight coast line with strong seasonal wind and heavy brifting sand are the typical features along the west coast of Taiwan. The variety of meteorology is not only influencing the configuration of the port but also demanding special alternatives to the selection of materials, construction methods, etc.

The design and construction methods of the composite type breakwaters used in Taichung Harbor were trying to triumph most of the meteorological and geographical disadvantages encountered as well as to meet the urgent construction schedule. The effort has been considered successful. The construction processes have appeared highly efficient. Fig. 1 shows the location of Taichung Harbor and the configuration of its breakwaters.

2 Relationships Between Caisson Composite Type Breakwater and Meteorology

During the winter, from October each year to February of the next year, the previaling wind comes from North and North-North-East with average speed of 10 m/sec at Taichung port. The prevailing wind in the summer used to come from South-West with considerably lower speed, not exceeding 9 m/sec except hitting by typhoon. Typhoons attack Taiwan in summer almost every year. They create much more significant waves than the prevailing wind does in the winter. Therefore, the methods of breakwater design of Taichung port were based on the waves created by the typhoons instead of the seasonal prevailing winds. Table 1 gives

* Assistant Engineer, Taichung Harbor Bureau, Taiwan, R.O.C.

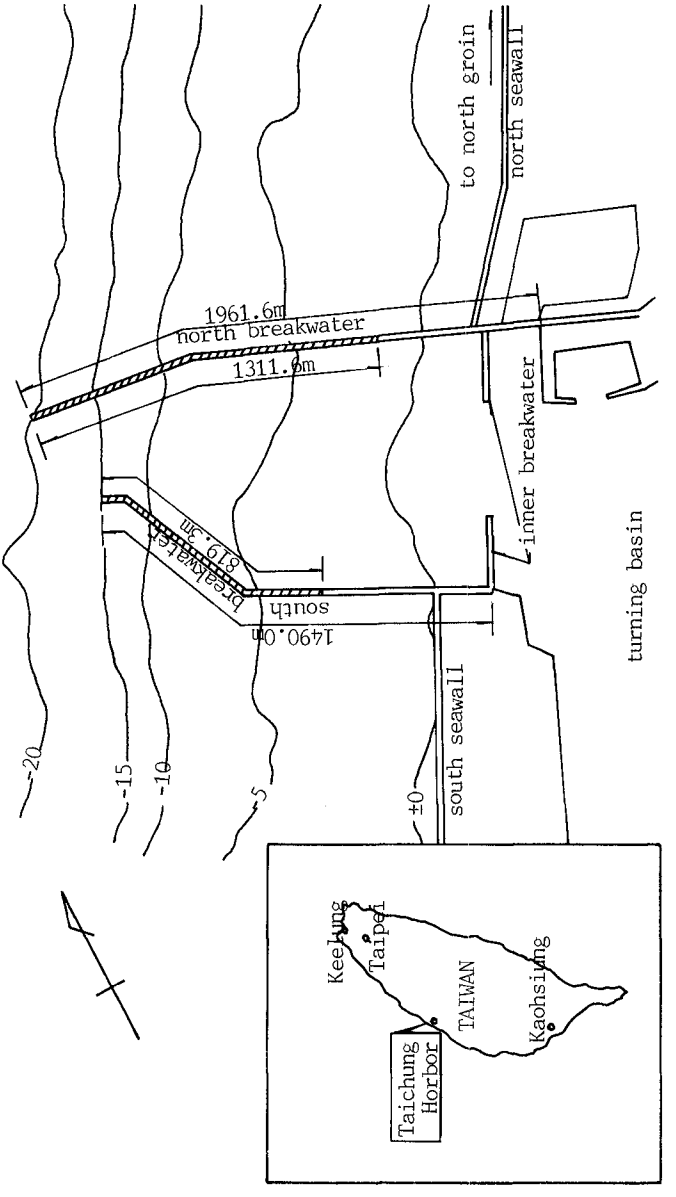

Figure 1. Location of Taichung Harbor and Layout of breakwater, shadow part indicates composite section

the significant wave height, at water depth -20m, of typhoons around Taichung Harbor, which was estimated by the "Wave Tracing Method" suggested by Dr. Ijima [3]. The max. tidal level of +6m was adopted as the H.H.W.L. (highest high water level) for the design.

Table 1. The estimated significant wave height & period at Taichung Harbor.

	Direction	Height (m)	Period (m)	Remarks
During typhoon	NNE	5.0	9.2	water depth = -20 m
	N	5.7	9.7	
	NNW	5.8	9.9	
	NW	5.4	9.9	
	WNW	5.0	9.8	
	W	4.7	9.3	
	WSW	4.6	8.7	
	SW	4.3	8.4	
During winter monsoon	N	4.0	8.0	water depth = -20 m
	NNW	4.0	8.0	

Drifting sand comes from two adjacent rivers; one is Tatu river on the south which carries about 0.2 million m^3 sand drifts northward in the summer, the other is Tachia river on the north with the sand amount around 0.8 million m^3 which goes southward particularly in the winter. There is about 1 million m^3 of sand being transported to the port and vicinity annually. Hence, the effect of preventing sand from settling in this harbor was considered being part of the function of breakwater.

The layout of this port was selected through a series of Model Experiment of Protection. The entrance width is 350m, navigation channel angles with 65°44' westward from the north, i.e. on the skew to the direction of prevailing wind. The length of breakwaters were determined accordingly with that the depth at the seaward end of north breakwater should reach -20m, and should be -15m deep at the end of south breakwater. Also, according to the Sand Drifting Model Test, the breakwater with vertical wall was chosen as typical cross section at places where the water depth is over-4m. The waves reflected by vertical wall breakwater could affect part of the approaching sand load away to the deep water (over -20m) area and the reserved settling place which located between north breakwater and north groin with the area more than 350 hectares. The reserved areas are dredged annually to provide adequate space for future sand deposits. This method provides good means to control sand free from drifting into the harbor [5].

Besides considering of harbor calmness, drifting sand control, vessel operation and construction economy ..., there was another reason for choosing composite type breakwater in Taichung Harbor; to account the property of its faster construction progresses and invulnerable characteristics.

3 Features of Caisson Composite Type Breakwater

3.1 Corresponding Data

The wave pressure acts on breakwater was computed by using Sainflou's Formula at the zoon where the wave is under the non-breaking condition. The Hiroi's Formula was used to calculate the wave pressure wherever the water depth is smaller than twice the height of approaching waves. The initial dimension of the proposed cross sections of composite type breakwater was determined through the estimated wave pressure and the Itoh's Expected Sliding Theory which checked out the possible lateral sliding displacement at any place of the breakwater with the maximum tolerance not exceeding 5 cm [4].

For easily constructing and conveniently towing, also for taking the full usage of caisson dock (its 115m long, 28m wide and 8.9m deep, can cast 4 caissons in one batch), the lengths of concrete caissons were setup to 18m and 24m, the widths varied from 14m to 18m depending on the water depth at the post position.

Final elevation of crown tops for northern and southern breakwaters, according to the estimated overtopping condition at north breakwater during monsoon season and at the south breakwater in the Typhoon period, are +10.2m and +8.6m, respectively [1].

The thickness of rubble mounded foundation was determined to be larger than 2m at any position, despite the good bearing capacity of sea bed around this area (silty sand, the blow count of penetration test at top 10 meters layer, $N > 10$; others $N > 30$) [1]. Mean while, to prevent the sand being washed out from the bottom of foundation by current and tide, vinyl mattress was unfolded to cover the surface of sea bed before rubble mounding. Fig. 2 illustrates the typical cross section of composite type breakwater at Taichung Harbor.

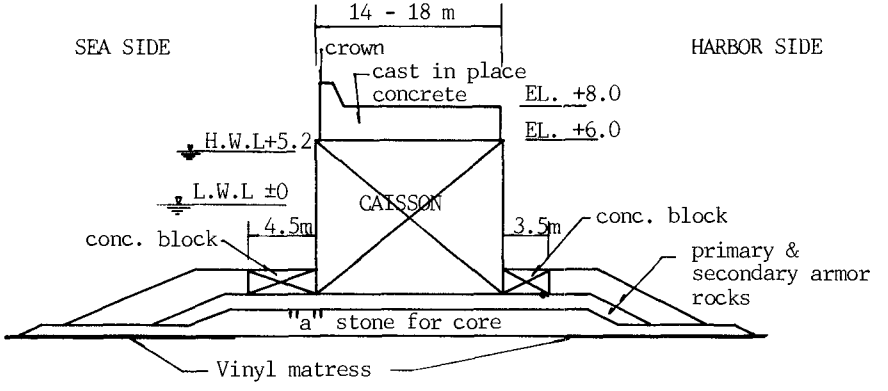

Figure 2. Typical cross section of composite type breakwater at Taichung Harbor

The length of north breakwater is 1961.6 meters with 1311.6 m in composite type. South breakwater is 1490 meters long with composite type 819.3 m.

3.2 Construction Procedure

Totally, 102 breakwater caissons had been completed within the first construction stage (1972-1977); 59 at north, 37 at south, 2 caissons at north groin and 4 at both inner breakwaters. In order to meet the urgent schedule, about 2/3 (71 caissons) of the total amount were built up on the sand beach instead of using dry dock, because the available work yard on beach was almost unlimited for each construction batch. In average, it took only 9.5 days to complete a caisson on the beach -- much shorter than erecting it in dock. Fig. 3 shows the caissons being made on beach were ready for floating out.

A well designed procedure which can be used to float out the caissons safely is the key for successful beach-made-caissons. Experiments of Model Floating and detailed survey during each caisson's floating out were made [2]. At the beginning, the Sit-to-Float method was used on the first two caissons of south breakwater. This kind of method was leading to low down the caisson into water levelly, then enable it floating out at high tide, by dredging and washing out the sand around the bottom of caisson at the same time. Fig. 4 indicates the steps of Sit-to-Float procedure. Unfortunately, stress concentrations were found on the bottom of that two caissons. Therefore, an alternative technique, so called Slide-to-Float method, was adopted as the proper way for all the other beach-made-caissons.

Figure 3. Caissons made on the beach where is dredged for harbor basin later

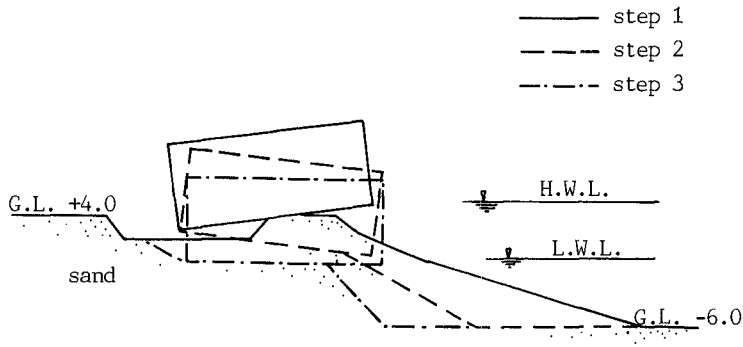

Figure 4. Procedure of caisson floating out -- Sit-to-Float. Steps: 1) dredging and washing out sand around caisson bottom; 2) caisson lowing down at L.W.L.(lowest water level) on its own weight; 3) caisson floating out at H.W.L.(highest water level)

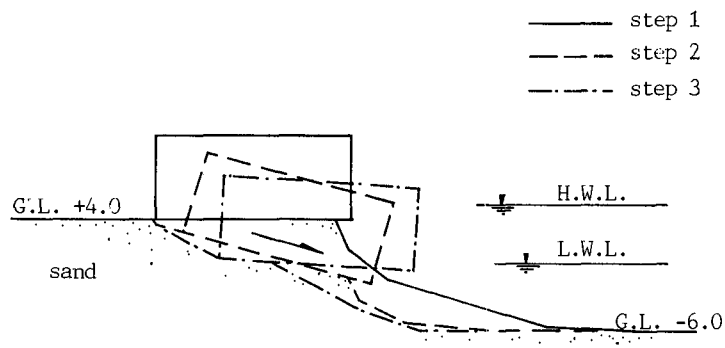

Figure 5. Procedure of caisson floating out -- Slide-to-Float. Steps: 1)dredging out sand under front toe of caisson; 2) caisson sliding toward water deeply at L.W.L.: 3) caisson floating out naturally at H.W.L.

In the method of Slide-to-Float, dredgers were used to cut the sand out from the front toe of each caisson to guide it sliding into water. Then, the caissons would float up for towing when tide flood. Because of the large tidal range (mean spring tide range: 4.59m) and the high friction of sand (angle of friction, ϕ, between 30° and 34°) at this area, caissons would not slide down abruptly. This process neither damaged the structure of the caissons nor hurt the working vessels. Fig. 5 illustrates the processes of Slide-to-Float method. Fig. 6 shows a caisson is sliding toward water under the operation of Slide-to-Float.

Because of the limits of water depth around the caissons' casting yard, wherever at dock or on beach, the constructed height of the caissons should not exceed 14m to ensure the floating out of caissons. Hence, for those caissons which final height beyond 14m were constructed up closely to 14m first. After that, they were towed to the high layer construction site and temporary storage area for continuously completion.

The whole construction sequence of composite type breakwater started from deploying center line, sounding out the elevation of sea bed, and paving PVC mattress. Cobble "a" - the stones with diameter around 30 cm were dumped to the site to constitute as the core of foundation before secondary armor rocks (0.3 - 1 ton) were casted. After the caissons were settled to position, they were filled with sand and gravels. The finishing procedures included pouring cap concrete, placing protective concrete blocks, tetrapods, and primary armor rocks (size 1 - 5 ton). It was considered to be totally completed after the crown had been concreted.

Figure 6. Caisson slides toward water under process of Slide-to-Float method

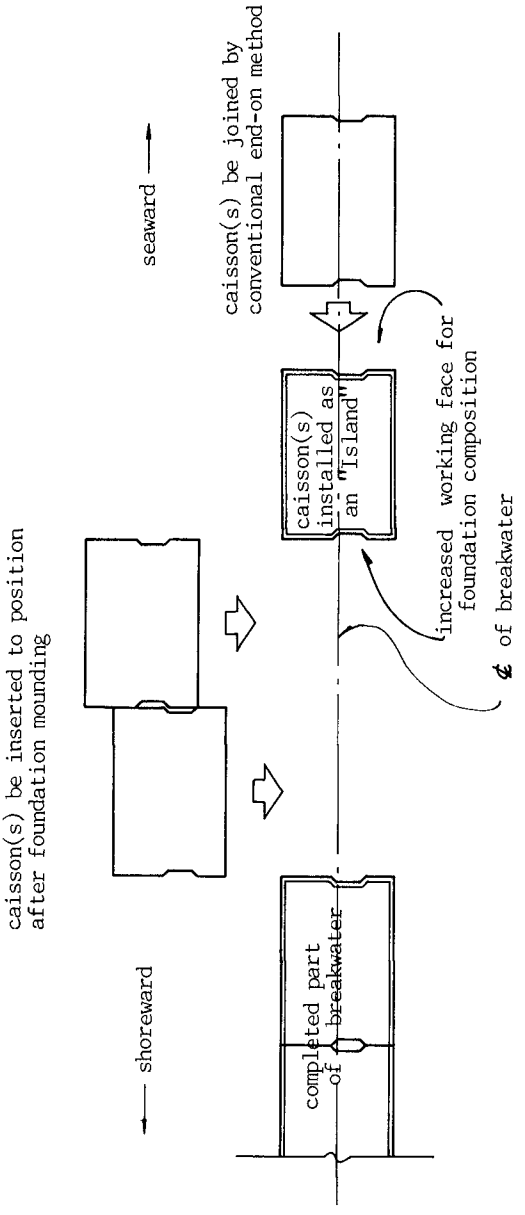

Figure 7. "Island" method of caisson installation

Figure 8. Installation of an "Island" caisson, which is aided by a pre-anchored 80 MT pontoon

Figure 9. Behind an "Island", a caisson is inserting to its position

Since the manufacturing of caissons was shortened significantly, and the workable time on the sea was comparably insufficient (96 caissons should be installed within 3 years), the disposition of installing caissons became critical. In addition to the conventional end-on progressive method, an "Island" method (or might call "Jumping" method) was introduced to increase the working faces to these breakwater construction project. The concept of this scheme, different from the conventional end-on method, is to post caissons some distance apart from the already installed breakwater, promise more working space to conduct consequent foundation rubble mounding, and then to complete this section of breakwater by inserting other caissons [6]. Fig. 7 illustrates the scheme of "Island" method. Fig. 8 shows an "Island" caisson is adjusting its position with the aid of a pre-anchored 80 MT pontoon. Fig. 9 shows a caisson is towed on the way to fill the space between "Island" and the end-on caisson.

4 Conclusion

The workable time on the sea of this project, 120-140 days per year averagely, was very short and urgent. Fortunately, however, the project was smoothly and punctually completed. The success should attribute to the careful and thorough planning, good use of long term and short term weather forecasting informations, etc. The most outstanding tact among these procedures are considered as successfully casting most caissons on the beach area where would be dredged as the channels later, and taking an unprecedented "Island" method to place the caissons.

5 Acknowledgements

The author would like to express his appreciation to Mr. C.C. Sha, Chief Engineer of Taichung Harbor Bureau, for his suggestions and the most help in the successful collection of historical records and data which enabled completion of the work.

6 References

1. CHANG, C.C. et al (1981) Caisson type breakwater of Taichung Harbor. Proc. Third Conf. of Harbor Technique, Taiwan pp. 7-10

2. HSU, C.Y. et al (1976). Report of caissons' construction and out floating from sand beach, Taichung Harbor.

3. JAPAN PORT CONSULTANTS, LTD. (1972) Primary report of wave estimation at Taichung Harbor.

4. TAICHUNG HARBOR BUREAU (1973). Study of engineering design at Taichung Harbor. pp. 2-11

5. TAICHUNG HARBOR BUREAU (1973). Study of model experiments of Taichung Harbor.

6. TAICHUNG HARBOR BUREAU (1976). Report of first stage construction, Taichung Harbor. Vol. II.