NEW JETTIES FOR TUNG-KANG FISHING HARBOR, TAIWAN

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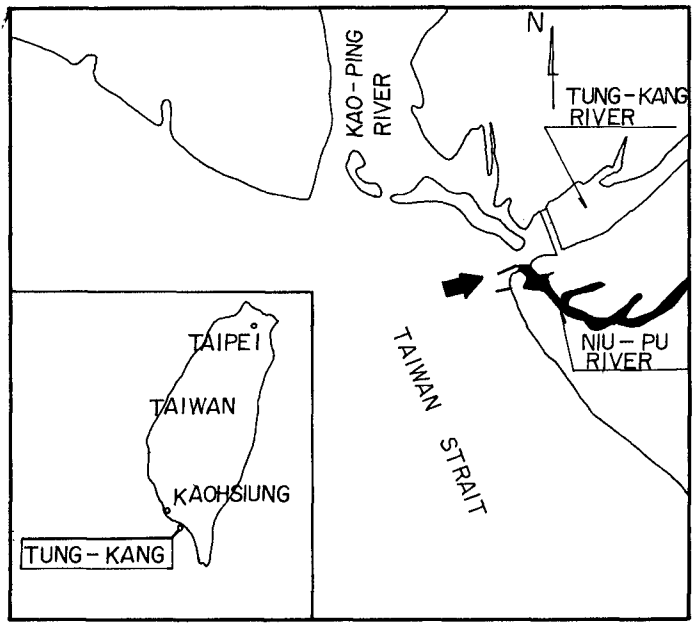
INTRODUCTION

Tung-Kang Fishing Harbor, which is about 16 km to the south of Kaohsiung Harbor, is a river harbor on the south-west coast of Taiwan. This harbor is located at the estuary of the Niu-Pu River, which meets the Tung-Kang River and the Kao-Ping River on the north side. (see Fig. 1) The original north and south jetties were constructed in 1959. Because the entrance is located at the meeting of the three rivers and the water depth at the entrance is shallower than that in the breaking zone, the entrance is easily chocked with sand during the summer season when the south-west wind and waves are strong. Therefore, dredging is always necessary to maintain the required depth. On the other hand, because of the increasing number of fishing boats and deeper draft, the port cannot function effectively. There-fore, how to keep the required water depth at the entrance and to obtain a wider and stable water basin is an urgent problem with this harbor.

Based on the sounding of 1973, the littoral drift is mainly from the south. In the next year the construction of a 176 m long new south jetty was begun to protect the entrance and to facilitate the sedimentation study. In 1975, the Taiwan Fisheries Consultants was appointed to undertake the investigation and long-term planning work. This project includes littoral process study, planning, model test and design.[1] Finally it is recommended that an adequate layout of south and north jetties can solve the problem of accretation of the harbor entrance.

The purpose of this paper is to describe some aspects with emphasis on how to prevent the shoaling of the entrance channel located at the meeting of the rivers.



Fig—1 SITE LOCATION

LITTORAL ENVIRONMENTAL CONDITIONS

Wind

Because of the lack of site data, those observed at Kaohsiung are referable. The wind data from 1951 through 1970 were analyzed.(2) Winds from north-northwest occur in the greatest part of the time and prevail during the months of September through April. Higher velocities are associated with typhoon passing this area or tropical depression which occurs in the South China Sea mainly during June through September. The strongest longshore winds with speeds ranging from 5.4 to 13.8 m/sec occur during the summer season and predominantly from the southeast.

Waves

Based on the wave data measured in 12^{m} of water at Kaohsiung Harbor, the predominant wave height is $0.5\text{-}1.0^{m}$, with wave period of $7\text{-}8^{sec}$ and from southwest.(3) The higher waves occur during the summer season, especially in the typhoon period.

Tide

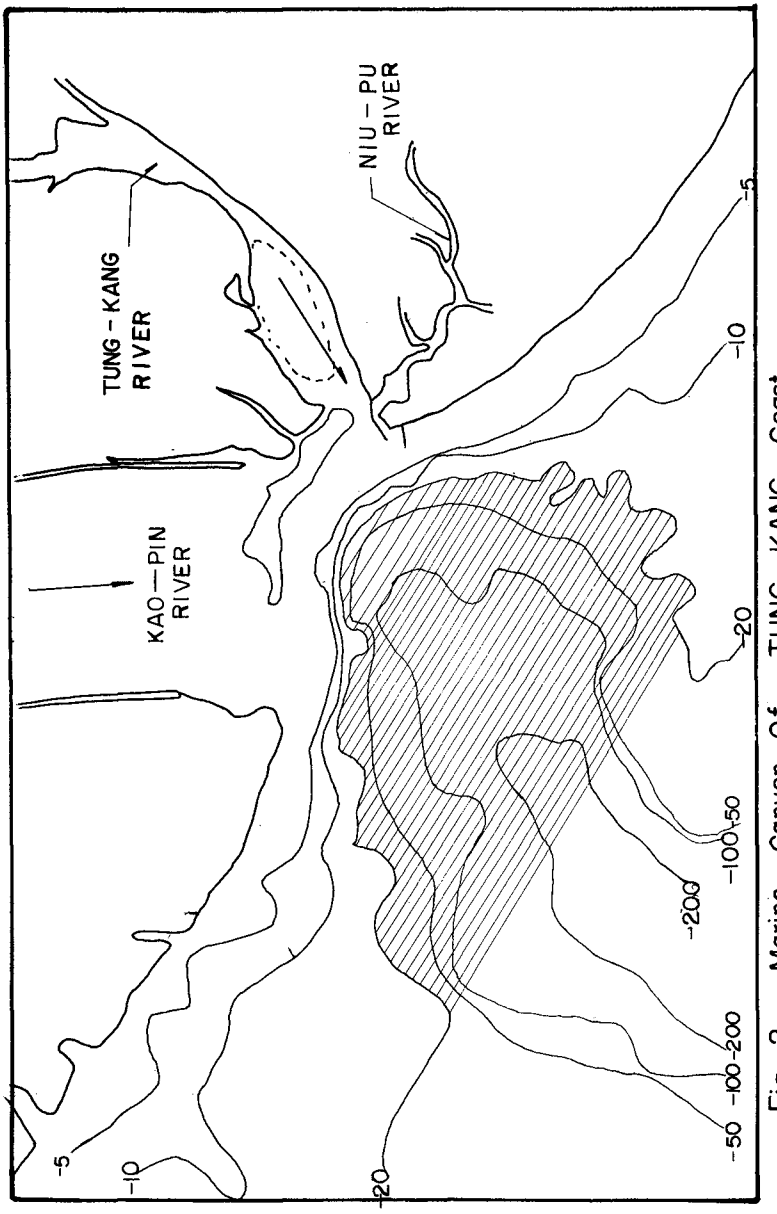
The spring tidal range is 1.3^{m}, the maximum water level was observed in 1969 at 2.7^{m} above low water level. This is due to the combination of spring tide and storm surge. The measured current speeds of both ebb and flood tide are below 0.5 m/sec.

Rivers

There are four rivers in the study area (see Fig. 1); except the three of them meeting at Tung-Kang Harbor, the Lin-Ben River is 10 km to the south of this harbor. The maximum measured discharge of the Kao-Ping River is $18,000^{cms}$, $1,470$ the Tung-Kang River and $2,950^{cms}$ the Lin-Ben River. The discharge in the Niu-Pu River is too small and negligible. The estimated annual sand volume transported by Kao-Ping River is 24 million cubic meters, 0.5 million cubic meters the Tung-Kang River and 1.5 million cubic meters the Lin-Ben River.

Topography off Tung-Kang Coast

Fig. 2 shows a deep marine canyon off this coast. Therefore most of the sediment dicharged from rivers are traped in it.



Fig—2 Marine , Canyon Of TUNG—KANG Coast

LITTORAL PROCESS

Bathymetry

From the bathymetric survey of September 1973, it was found that the littoral drift was mainly from the south. As shown in Fig. 3, the sand bars were formed at both heads of the original north and south jetties. In the next year the construction of a 176^{m} long new south jetty (see Fig. 7) was begun to protect the entrance and to facilitate the sedimentation study. For further study, three other soundings were conducted in May 1975, September 1975 and June 1976. The lengths of the newly constructed south jetty in these three soundings were 120^{m}, 176^{m} and 216^{m}, and the depths at the jetty head were 1.8^{m} (below low water level), 2^{m} and 4^{m} respectively. The results of the sounding were used for comparing changes of contour. So the sand sources and seasonal sea bottom change in the region between shoreline and some water depth contour could be interpreted. The influence of the newly constructed south jetty on the behavior of littoral drift was also evaluated.

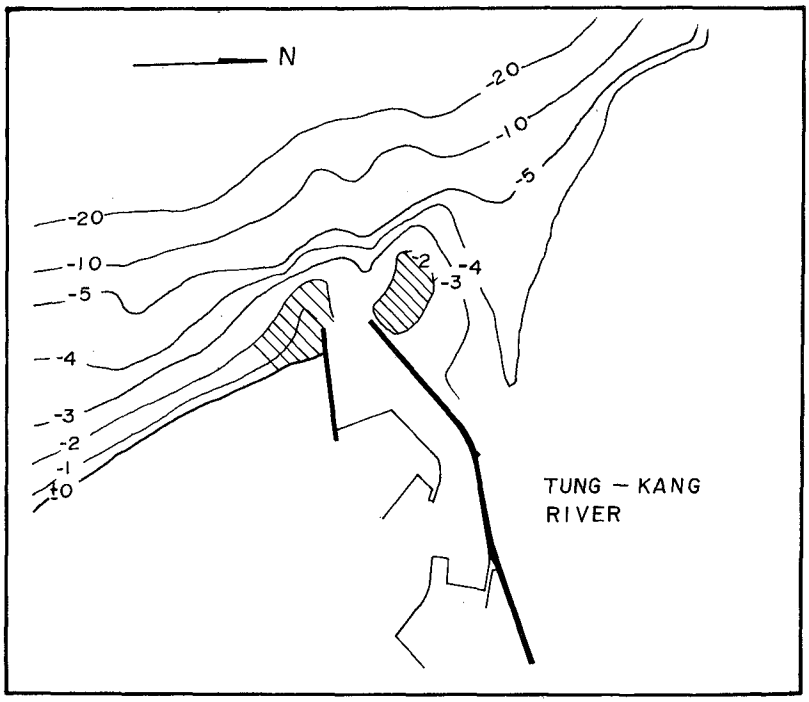
Grain size Distribution

With the last two soundings littoral materials were also sampled for analyzing grain size and size distribution in the study area.

The median grain size was analyzed, from the size distribution overall the study area, the following results could be obtained. 1. The June 1976 data showed that the relatively coarse sands were distributed in the range from -2 to -3^{m} depths, while those of September 1975 were in -5 to -6^{m} depths. They were positioned in breaking zone, and during typhoon period the position moved seaward. 2. At the mouth of the Tung-Kang River, the median size D50 was up to 0.6^{mm} which was rather coaser than at the other place. From this we can know that they came from the Tung-Kang River or the Kao-Ping River. The finer sands were transported by wave current and the coaser ones remained behind. 3. At the entrance of the harbor, the sand was fine because of low wave energy there.

Dredging Record

To provide the required navigation channel, dredging work was conducted during the period from 1973 through 1975. The monthly dredging volume is listed in Table 1, which shows the annual volume to be around 100,000^{m3}.



Fig–3 SOUNDING OF SEPTEMBER 1973

Table 1. Records of Dredging Volume

Month \ Year / Volume	1973	1974	1975	1976
1	3,400	6,300	13,442	7,600
2	9,100	9,450	5,600	7,400
3	9,270	11,600	10,000	-
4	7,250	9,200	11,000	-
5	10,410	8,400	13,300	-
6	11,415	6,800	6,300	-
7	3,970	8,000	9,200	
8	5,970	4,900	1,200	
9	14,580	11,400	9,750	
10	7,160	9,600	5,560	
11	8,200	8,240	9,600	
12	6,480	9,270	9,200	
total	97,250	103,610	104,152	

Seasonal Changes of Shore

They were analyzed by comparing the survey of May 1975, September 1975 and June 1976.

Summer Season: In the area immediately south of the new south jetty, the rip current induces by the jetty was obvious and deeply affected the foreshore and inshore topography. Along the shoreline accretion and erosion occured at different positions relative to the new south jetty. Due to the action of waves arriving from WSW to SSW, accretion occured in the area from the south jetty to a line approximately 200^{m} south. From the 200^{m} line to the line of 600^{m} south, the concentrating rip current made this area eroded evidently. While southwards the rate of erosion decreased

and accumulation occured by the supply of the southerly sand. Inspecting the onshore-offshore change, the influence of rip current was down to the depths between -4^m and -6^m. Deeper than this, there was accumulation because of slower current and abundant supply of material.

The area north of the new south jetty was mainly affected by the sand from the Tung-Kang River and the Kao-Ping River. Two impounding zones could be found in the lee of the south jetty and in the zone immediately north of the north jetty respectively. In the former case, littoral material moved along the outer face of the jetty and deposited in the relatively calm water in the lee of the structure. While in the latter case, sand transported by the rivers accumulated in the zone between the north jetty adjacent to the Tung-Kang River, due to slower water flow and wave current on the reverse at the river mouth. The accumulated sand may be transported by diffraction waves to deposit at the entrance. Fortunately, most of the sand there is moved by northward longshore current to the deep marine canyon off the mouth of the Kao-Ping River. This is why the samll scale Tung-Kang Fishing Harbor could be maintained by dredging about $100,000^{m3}$ of sand every year, as shown in Table 1.

Winter season:During the winter months, the approaching waves shift to the west direction and more perpendicular to the shoreline. So both the impounding capacity of the new south jetty and the southerly littoral drift are decreased. Although the rip current becomes slower, the shortage of sand supply made the erosion area moved northward. While to the south of the 600^m linc, the volume accumulated still increased and also moved northward due to the continuous supply of sand. Rapid erosion in the area north of north jetty is due to the decrease of sand from rivers during the winter months. The bar formed during the summer season was moved northward or transported seaward to the deep marine canyon by waves.

From the above analysis, the deep marine canyon is an effective sink to trap the large volume of sand transported from the Kao-Ping River. The orientation of the coast makes the direction of advancing wave toward the shore stable, and create a coast-longshore current from south to north, these two local conditions are very important for solving the entrance stabilization problem.

HYDRAULIC MODEL TEST

To prevent the sand from entering the entrance, both the newly constructed south jetty and the north jetty should be adequately extended. This was studied by using hydraulic model test conducted in the laboratory of Chung Hsing University[4].

The south jetty is mainly to stop the southern longshore drift and let it bypass the entrance. The extended north jetty is not only to provide a deeper entrance channel but also to reflect the waves to transport the sand at the head to the north. Besides, some short groins connected to the south bank of the Tung-Kang River can change the flow direction so as to discharge the sand away from the entrance. Based on these principles, the jetties were arranged and verified by model test.

A distorted scale (1:75 vertical and 1:150 horizontal) movable-bed model in which fly-ash with median diameter D_{50}=0.08mm and specific gravity S_m=2.02 was used as bed load. The wave generator was only 9m long. In order to have a larger scale model, the model was divided into two parts. (see Fig. 4) Part A included the area from the entrance to a point 1000m from the south of the new south jetty. The test was principally on the southern longshore drift. Part B included the area between the lines 300m to the south and 1000m to the north of the entrance. This part covered the estuary of the Tung-Kang River. The test was mainly on the sand from the river. The test was carried out with a number of cases with different layout of jetties.

In part A, five cases and thirteen runs were carried out with various wave conditions and durations. The results suggested a layout in which the south jetty was 410m including the shore connected portion of 350m long, then turning to the north-west and widening the north jetty so as to have a longer head for reflection waves. (see Fig. 5) In this case, no obvious accretion took place in the entrance channel; accretion occured around the north jetty where the counterlines moved seaward. The current induced by the new south jetty transported sand in the south-west direction. This corroborate the field investigation results.

In part B, five cases and seven runs were carried out. Besides various wave conditions and durations, the discharge and sand from the Tung-Kang River was also simulated. The results suggested a layout in which

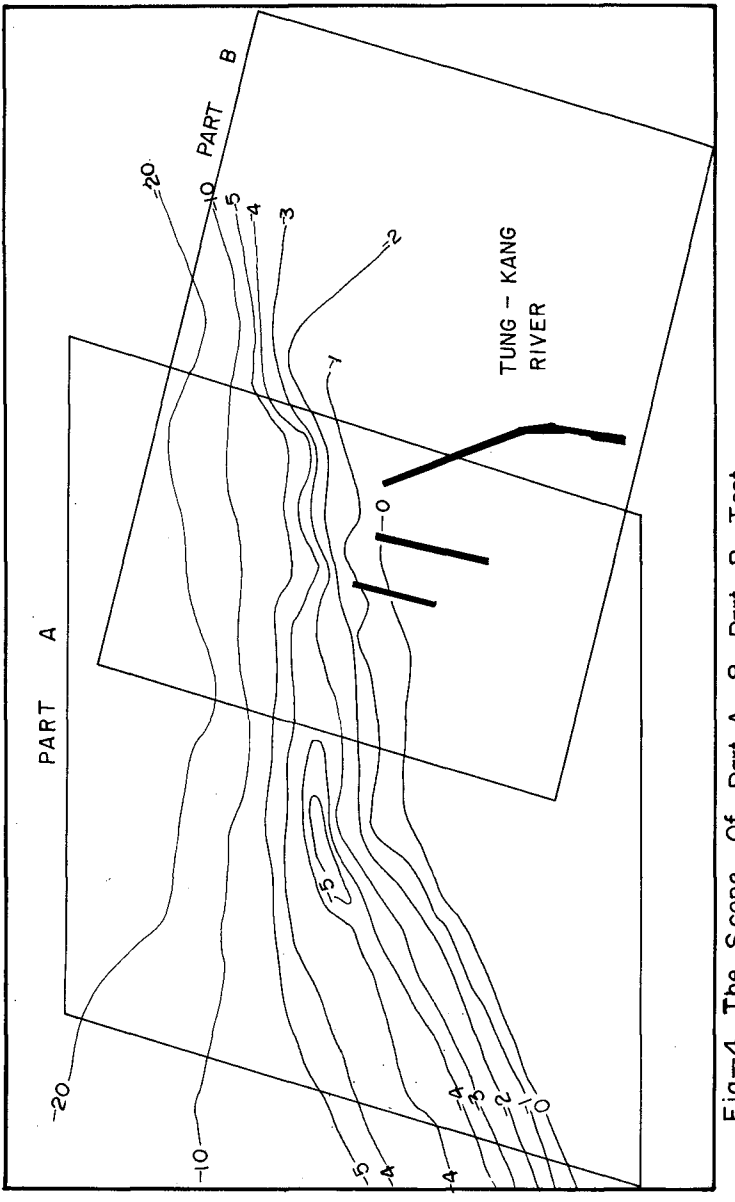
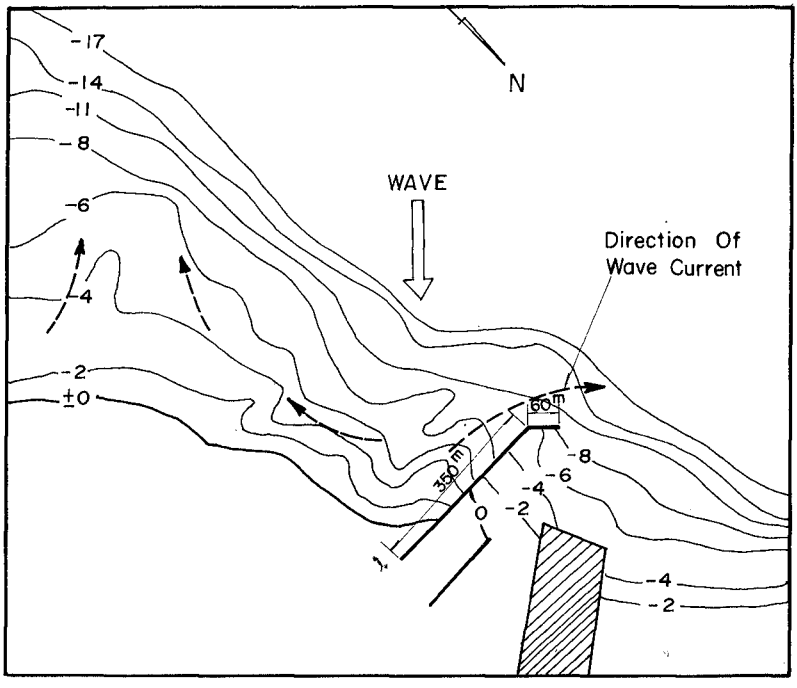
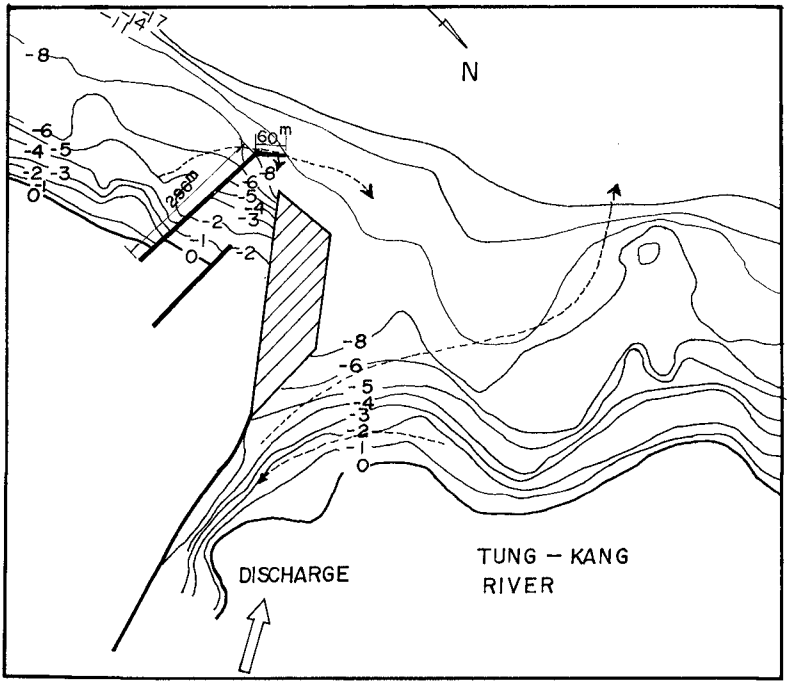


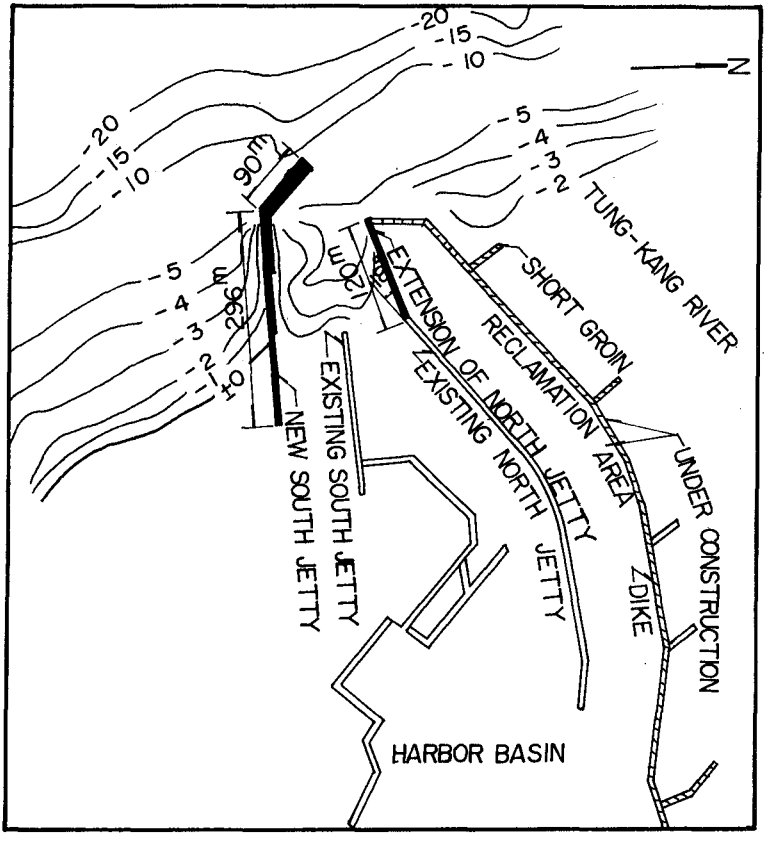
Fig-4 The Scope Of Part A & Part B Test



Fig—5 PART A TEST



Fig–6 PART B TEST



Fig—7 LAYOUT OF NEW JETTIES

the length of the new south jetty was 356m including the shore connected portion of 296m then turning to the north-west, and the north jetty was turned clockwise by 18° from the head of the existing north jetty and lengthened by 120m. (see Fig. 6) To reflect the waves at the head of north jetty so as to transport the sand apart, a reclamation area on the north side of the north jetty was suggested so as to have a wider head to reflect the incident waves. In this case, the southern longshore drift could by-pass the entrance without accretion because of the reflected waves from the north jetty head. The sand discharged from the Tung-Kang River was far away from the entrance due to the action of reflected waves and the effect of the reclamation area.

FINAL LAYOUT AND STRUCTURE TYPE

The final layout is as shown in Fig. 7. The new south jetty was lengthened by 30m so as to have a calmer basin. The first 176m section was rubble mound type armoured with holtripod. The other portion of 60m long was composite-caisson type. The width of caisson at head section is 15m, 8.5m high and 12m long. Composite-Caisson type was also adopted for north jetty. The construction work of the new south jetty and the extension of the north jetty was completed on 1979. The reclamation area, dike and short groins will be built in the following years.

CONCLUSIONS

(1) A careful field investigation of littoral process is helpful to the study of a samll scale harbor which is located at the meeting of rivers.

(2) A prototype jetty (if possible) for aiding the study of longshore drift is very effective.

(3) A physical hydraulic model is proved to be an important tool for the functional design of jetty system for entrance channel with complicated littoral drift phenomema.

(4) An adequate arrangement of jetties can make the diffraction and reflection waves play important roles in the sand bypassing system.

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