REPORT ON THE SURVEY FOR THE SECOND ENTRANCE CONSTRUCTION PROJECT AT KAOHSIUNG HARBOUR IN TAIWAN

JUNE 1965

OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

THE SECOND ENTRANCE CONSTRUCTION PROJECT AT KAOHSIUNG HARBOUR

FOREWORD

The Government of Japan has, at the request of the Government of the Republic of China, entrusted the execution of a basic survey for the 2nd Entrance Construction Project at Kaohsiung Harbour to the Overseas Technical Cooperation Agency. The Agency dispatched a survey mission headed by Mr. Y. Yanagisawa and consisted of six members, which stayed in Taiwan from March 8th to April 3rd, 1965.

The survey mission conducted a joint study with the officers of Kaohsiung Harbour Bureau regarding the estimation of the natural condition and the execution programme of the breakwater construction. The mission, having analyzed the data collected and discussed the execution programme after its return of Japan, hereby submit this report.

The Agency, as an executive organ of the Government of Japan, has been performing such technical cooperations as the offer of consulting services to, dispatch of experts to and induction of technical trainees from developing countries.

Nothing would be more gratifying to us, if this report could be of any contribution to the promotion of the 2nd Entrance Construction Project at Kaohsiung Harbour as well as to the furtherance of the amity, friendship and economic relations between Japan and the Republic of China.

June 1965

SHIN-ICHI SHIBUSAWA

Director General,

Overseas Technical Cooperation Agency

Report on the survey for
the Second Construction Project
at Kaohsiung Harbour

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CHAPTER I

INTRODUCTION

1. Purpose of survey

It is anticipated that, with the prospective increase in foreign trade, the entrance of Kaohsiung Harbour will turn out to be a bottleneck in the navigation of vessels. It is for this reason that the 2nd Entrance Construction Project is being contemplated.

The first step to be taken is to draw up a feasible plan. In the course of project formulation, extensive studies will have to be made in connection with winds, waves, tidal current, littoral drift, silting and scouring, etc. Therefore, a large scale surveying and observation should be made in order to collect these basic data. Apreliminary layout of the entrance can be made after those data are available. Then model tests will be conducted. The project will be finalized, based upon the findings of the model test.

The Government of the Republic has requested our technical cooperation for the above works as follows:-

(1) For surveying:-

a) Assistance in drawing up a surveying and observation plan.

b) Recommendation and assistance in the use of new instruments for survey and observation.

(2) For designing:-

a) Assistance in formulating a preliminary layout and conducting model tests.

b) Assistance in blueprinting the final project.

In compliance with the requests, the Japanese Government has executed this survey in the hope of adding another cornerstone to the foundations of the amity and friendship between the two countries.

2. Members of survey mission

Yonekichi YANAGISAWA, Leader of the mission
Advisor, Overseas Technical Cooperation Agency
Ex-Director, Maritime Safety Agency, Government of Japan

Yukio NIIZUMA
Chief engineer, Japan Port Consultants Ltd.
Former Vice-Director, 2nd Harbour Construction Bureau, Ministry of Transportation

Yasumaru ISHII
Ex-Head, Soil and Structure Division, Port and Harbour Technical Research institute, Ministry of Transportation

Tomoharu ISHIWATA
Former Staff, Construction Section, Port and Harbour Bureau, Ministry of Transportation

Yoshiyuki ITO
Chief, Breakwater Laboratory, Port and Harbour Technical Research Institute, Ministry of Transportation

Keisuke HISATAKA
Staff, Overseas Technical Cooperation Agency

3. Itinerary of the survey mission

March		
8, Mon.	Tokyo→Taipei	Visit to Mr. Tao Sheng-yang, Director of Secretariat, Council for International Economic Cooperation and Development
9, Tues.	Taipei	Visit to Embassy of Japan Visit to Mr. Chang Chi-cheng, Executive Vice-Minister, Ministry of Economic Affairs Obtained materials at Taipei Meteorological Observatory
10, Wed.	Taipei→Kaohsiung	Obtained outlined informations on Kaohsiung Harbour Extension Project Field inspection of extension works
11, Thurs.	Kaohsiung	Preliminary meeting with officers in charge at Guest House of the Bureau Obtained data at Kaohsiung Weather Station Inspection of inner harbour
12, Fri.	"	Study of data at Guest House Inspection on proposed site of 2nd Entrance
13, Sat.	Kaohsiung⇄Tainan	Inspection of hydraulic model study at Cheng Kung University Inspection on coast and harbours between Tainan and Kaohsiung
14, Sun.	Kaohsiung⇄Tunghsiang	Inspection on coast and harbours between mouth of the Kaoping-chi and Kaohsiung
15, Mon.	Kaohsiung	Study of data at Guest House
16, Tues.	"	"
17, Wed.	"	Reported findings of survey to officers in charge of Harbour Bureau
18, Thurs.	Kaohsiung→Taichung	
19, Fri.	Taichung	Reported to Mr. Huan Chiek, Governor of Taiwan Province and Mr. Chen Sheng-huang, Commissioner, Department of Communications
20, Sat.	Taichung→Taipei	
21, Sun.	Taipei	
22, Mon.	"	Reported to Embassy of Japan Submitted an interim report to CIECD
23, Tues.	Taipei⇄Keelung	Inspection of Keelung Harbour
24, Wed.	Taipei⇄Shihmen	Inspection of Shihmen Reservoir (Mr. Ishiwata left for Japan)
25, Thurs.	Taipei	Reported to Ministry of Economic Affairs
26, Fri.	Taipei→Kaohsiung	(Mr. Yanagisawa, Mr. Niizuma and Mr. Ishii left for Japan)
27, Sat.	Kaohsiung	Inspection on coast between Feng Pi-ttou and Hungmaochiang
28, Sun.	"	
29, Mon.	"	
30, Tues.	"	Inspection on coast between Hungmaochiang and Chihou Discussion and explanation of natural conditions at meeting
30, Wed.	Kaohsiung→Taichung	
April		
1, Thurs.	Taichung→Taipei	
2, Fri.	Taipei⇄Hua Lienchiang	Inspection of Hua Lienchiang
3, Sat.	Taipei→Tokyo	(Mr. Ito and Mr. Hisatake left for Japan)

4. Republic officers in charge

The survey mission takes this opportunity to express its gratitude for the cooperation by the officers mentioned below and other persons concerned.

Kaohsiung Harbour Bureau	Mr. Lee Lien-chih, Director
	Mr. Chang Lien-yung, Chief Engineer
Second Entrance Planning Office	Mr. Kung Chien-yi, Engineer
	Mr. Hu Chin-chang, Engineer
	Mr. Yeh Jung-hsiang, Engineer
Extension Work Office	Mr. Ting He-nien, Engineer
	Mr. Ma Cheh-chun, Engineer
	Mr. Lin Ta-lung, Engineer
Cheng Kung University	Prof. Tang Lin-wu
	Prof. Chang Yu-tien

5. Interim report submitted to CIECD

(1) Estimation of natural conditions

The estimation of the natural conditions, which constitutes the most important and basic subject of investigation, requires an extensive study as detailed as possible. For this purpose, the materials which had been prepared in Japan were carefully checked up with those available in Taiwan, and studies and discussions were made jointly by the Chinese and mission experts in order to formulate the observation methods and programmes concerning the wind, wave, tidal current, tide and littoral sand.

(2) Brief consideration of the construction programme

The construction of the breakwater and dredging of the fairway, which are essential factors of the project, have been carefully discussed. As regards the former, the Kaohsiung Harbour Bureau has already prepared a preliminary construction plan based on the experience in the construction work at Keelung Harbour. Feasible as it is, there still remains some apprehension for the high cost of its works, and alternative plans are being studied in comparison with it. Arrangements have been made that the model tests for determining the shape of the entrance will be conducted at the Cheng Kung University.

(3) Present situation and prospective plan of Kaohsiung Harbour

The cargo amount in Kaohsiung Harbour, which accounts for 2/3 of the total cargo traffic of all ports in Taiwan, is on the steady increase. In view of the prospective development of Taiwan, the cargo traffic in Kaohsiung is presumed to increase beyond the estimation, as the other existing harbours leave little room for further extension, the heavy littoral sand along the west coast north of Taiwan makes it difficult to open new ports, and the absence of suitable hinterland in the east side will render a new harbour on the locality hardly practicable. It is considered necessary, therefore, to review the Kaohsiung Harbour Project intergrated and co-ordinated with the 2nd Entrance Project and the industrial expansion plan in this district.

(4) Conclusion

The 2nd Entrance Construction Project seems to be feasible since it is little affected by adverse factors including the littoral sand. For the sake of security, however, in executing such a great project, it is considered appropriate to make another joint study between the Chinese and Japanese experts in October this year, after having carefully observed the behaviours of typhoons during this summer. It may also be advisable for the administrative officers and engineers of the Kaohsiung Harbour Bureau to come over to Japan to inspect the actual situations of some harbours in Japan, and, for Japanese experts to visit Kaohsiung for observation.

CHAPTER II

SUMMARY

The principal subjects of survey for the formulation of the 2nd Entrance Construction Project at Kaohsiung Harbour are the planning of the breakwater construction and the dredging work of the fairway as well as the estimation of natural conditions which constitutes the basic data for the project. In addition, it may be necessary to reconsider the future development of Kaohsiung Harbour in relation to the 2nd Entrance Project.

1. Natural conditions

The natural conditions to be studied consist of the winds, waves, tides and tidal currents, littoral sand, soil and earthquake. The study will be conducted according to the following steps:-

i) Collection and analysis of available data;

ii) field inspection and collection of on-the-spot informations;

iii) performance of additional observation.

The findings of the analysis of the materials obtained during our survey is as follows:-

(1) Wind: The NNE monsoon prevails all over Taiwan in winter, while in summer the monsoon is weak and frequent attacks of typhoon were observed, from the records accumulated in a long period at Kaohsiung Observatory.

(2) Wave: From the eye-observation records of Kaohsiung Observatory, informations from a pilot and estimates from the wind records, the winter NNE wind generates fairly large waves in Taiwan Strait. Kaohsiung, however, is free from their direct attack by dint of the neighbouring topography, and visited by the resultant waves consisting of their refracted or diffracted waves and local wind waves. The wave height is generally less than about 1 m and even the maximum may not exceed 2 m. In summer, the waves due to monsoon are weak, while those due to typhoon are prevailing; the characteristics of the latter are different according to the course and scale of typhoons.

In view of the fact that the existing south breakeater, whose design wave height is presumed to be 6 m, has stood against the typhoon for a long time, the equal design wave height may be applicable to the second entrance.

(3) Tide: The tidal observation records inside the harbour are available. According to them, the tide ranges in and out of the harbour are nearly equal and both about 1 m. The tidal observation records by the Harbour Bureau show scarcely any secondary oscillations

and unusually high tides.

The velocity of the tidal current is 1 knot near the breakwater head, and 1.5 knots at the narrow part of the entrance channel, respectively. This current contributes to maintaining the fairway now, but it is conceivable that the velocity will decrease after the completion of the second entrance, bringing about the siltation of the fairway.

The current outside the harbour is negligible.

(4) There does not seem, in view of our field inspection, to exist any considerable amount of the littoral sand along the coast between the Tsengwen-chi and Kaoping-chi, although there is some shift of sand due to typhoon and flood. The prevention of erosion might be rather necessary in the vicinity of the proposed site of the second entrance.

The water depth in the vicinity of the second entrance, as in the cases of the contour lines of - 5 m and - 10 m, have undergone almost no change excepting the nearby part of the south breakwater head, according to the comparison of two editions of marine charts, 1938 and 1955.

The amount of dredged materials from the navigation channel outside the harbour has been on the increase. This may be caused by the mud, dredged from the inner harbour by sand pump into outer sea, coming around to the channel.

(5) The result of the boring and soil tests, conducted for the Extension Project, shows that there is a thick layer of fine sand in the bottom, and the conditions of the foundation are not so favourable; therefore, deep foundation work will be necessary for heavy structures.

Judging from the seismological records, there will be no great earthquakes.

Based on the above-mentioned materials, an investigation programme consisting of the following items has been formulated:-

i) Littoral sand survey .... depth sounding; shoreline survey; bottom sampling.

ii) Tidal current .... its effect on the maintenance of water depth of existing fairway; influence of the retardation of the current on water depth; investigation of conditions of comparable harbours.

iii) Waves .... observation by means of wave-height gauge; eye-observation from the lighthouse; estimation from meteorological records.

iv) Model test of breakwater .... wave sheltering effect (scale: 1/100); structural design (scale: 1/30)

2. Construction work programme

The layout of the breakwaters and the design conditions of their structure will be finally determined after the model tests as well as the survey of the natural conditions have been completed. Consideration of the construction programme has been tentatively made on the basis of the original layout drawn up at Kaohsiung Harbour Bureau, assuming the design wave height to be 6 m.

Three types of the structure of breakwater have been taken up for comparison: two types of composite caisson breakwater and a tetrapod type. The construction cost of a rubble-filled caisson type breakwater seems lowest. In order to establish a construction programme, design and engineering conditions should be determined on the basis of such studies as follows:

1) For establishment of design conditions:

   Layout of breakwaters;

   Characteristics of design wave;

   Conditions of foundation.

2) For determination of execution programme:

   Workable days per year;

   Survey of stone deposits and quarrying programme;

   Stone transport programme;

   Caisson yard programme.

3. Prospective development plan of Kaohsiung Harbour

In connection with the 2nd Four-year Plan of Taiwan (1957 - 61) the Extension Plan of Kaohsiung Harbour was started in 1958. It consists of such important works as the land reclamation, dredging of the fairway, construction of wharves and enlargement of the fishing port. port.

Furthermore, the New Commercial Harbour Project is being contemplated, to be completed during 1965 - 69, in order to build the facilities necessary for dealing with the estimated amount of cargo of 6,950,000 tons in 1969.

An increased amount of the sea-borne cargo due to the economic development of Taiwan will have to be dealt with by the construction of new harbours as well as the extension of exiting ones. There is little room for enlargement in such existing ports as Keelung and Hualien. The hinterland of the east coast is limited, and there is heavy littoral sand on the west coast north of Tainan; these factors will make it difficult to open new harbours. Such being the case, it is quite natural that the extension of Kaohsiung Harbour should be regarded as the sole means of coping with the situation.

The amount of cargo transacted in Kaohsiung has been rapidly increasing, amounting to 5,980,000 tons in 1964, which represents nearly two-thirds of the total cargo traffic of the whole of Taiwan. It is presumed from this quantity and increase rate that the total amount will come up to 9,000,000 tons in 1969, including 5,000,000 tons of general cargo.

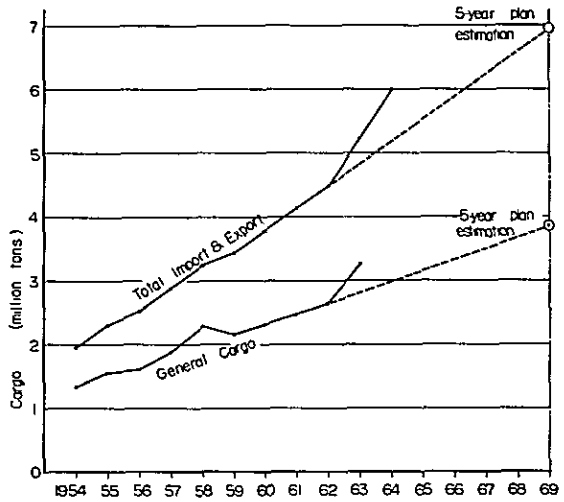


Fig. 2-1 Cargo Amount of Kaohsiung Harbour

It is anticipated, with the prospective increase in foreign trade, that the harbour entrance will prove a bottleneck for the passage of vessels, which has resulted in the formulation of the 2nd Entrance Construction Project. The original extension project, which was drawn up without regard to the 2nd Entrance Project, leaves something to be desired in that it seems to lack in the establishment of an overall plan of the industrial zone; that the inner water surface is small, and the layout of the fairway inadequate. The new Commercial Harbour Development Project was formulated on the basis of the presumed amount of cargo, which would run into 6,950,000 tons in 1969, including 3,800,000 tons of general cargo; this project does not seem to properly match the recent trend of cargo increase.

CHAPTER III

CONCLUSIONS AND RECOMMENDATIONS

(1) The construction of the 2nd entrance at Kaohsiung Harbour is feasible. More detailed investigations, however, are indispensable to formulate the construction programme.

(2) It is necessary to carry out the investigation programme of the natural conditions, and then determine the natural design conditions to be used in the construction programme, after having obtained the necessary data. Then model tests should be conducted applying that natural design conditions in order to determine the layout of the breakwater and fairway.

(3) As for the structural type of the breakwater, the rubble-stuffed caisson type is considered advantageous. The total cost for the construction of the breakwaters and dredging of the fairway is estimated at NT$500,000,000, which would verify that the original estimate value made by Kaohsiung Harbour Bureau would be appropriate.

A detailed survey will be necessary of the quarry, transport route and caisson yard, in addition to the natural conditions, in order to finalize the construction programme.

The execution period of works, originally set for seven years by Kaohsiung Harbour Bureau, is considered appropriate. However, it is also necessary to take into consideration the shortening of the period, weighing the needs of its early completion, reduction of the interest on the construction cost and inevitable increase in the execution capacity.

(4) It is necessary to review the harbour facility plan, commercial, industrial and fishing, establish the industrial zone plan, in view of the rapidly increasing trend of the cargo amount which is well over the estimation, as well as the construction of the second entrance to the harbour.

In formulating the industrial zone plan, thorough considerations should be given to such questions as the supply of industrial water and conversion of farm land into industrial use.

(5) Japanese experts had better be dispatched for the performance of investigation and observation of the natural conditions. A joint study is expected to be made again by Chinese and Japanese experts, with new informations which will be obtained during the typhoon season.
It would be very advisable for the promotion of the project to invite to Japan those administrative officers and engineers who are in charge at Kaohsiung Harbour Bureau in order to inspect the actual situation of some harbours in Japan.

CHAPTER IV

NATURAL CONDITIONS

1. Introduction

In this chapter will be discussed natural conditions necessary for the construction of the second entrance of Kaohsiung Harbour. Regarding each item of such natural conditions as wind, wave, tide, littoral drift, soil and earthquake, analized results based on the available data and some pending problems to be further studied will be referred to, and the future investigation programme will be finally established.

2. Wind

2.1 Wind characteristics in Taiwan

(1) In the vicinity of Taiwan, the NNE monsoon along the edge of the high pressure over the Continent is prominent in the winter season. The wind is fairly strong with a long duration.

(2) On the contrary, the monsoon in summer is very weak, unstable and almost negligible from a viewpoint of wind wave generation.

(3) Strong wind in summer is mainly due to typhoon. The characteristics of storm are different according to the course and scale of typhoon and can be classified into several categories.

(4) Typhoons sometimes come even in winter. Tropical depressions should also be taken into consideration.

(5) Table-4.1 is one of the daily wind records at Peng Hu Islands representing the wind characteristics in Taiwan Strait (from Printed Weather Chart, 1962 and 1963, Meteorological Agency, Japan).

(6) Table-4.2 is one of the monthly wind records in several places in Taiwan (from Taiwan & Nansei Shyoto Pilot, 1962, Hydrographic Department, Maritime Safety Agency, Japan).

(7) The above-mentioned general tendency is clearly found in Table-4.2, there are slight differences according to places though. Kaohsiung has its peculiarity in having the most frequent wind of NE direction throughout the year.

(8) Table-4.3 is another monthly wind record at Kaohsiung similar to Table-4.2, but with different statistic periods (From Japan Waterway Directory Vol.6, 1914).

2.2 Wind characteristics in the vicinity of Kaohsiung

(1) As to the fact that the most frequent wind direction in winter in Kaohsiung is NW, the phenomenon of wind divergence in the southern part of Taiwan Strait may be counted as one of the reasons.

(2) The most frequent wind direction in summer is different according to the statistic period. This means the weakness of the summer monsoon as already mentioned.

(3) Table-4.4 shows the wind frequency classified by wind direction and wind force in 1961 to 1963 measured at Kaohsiung Weather Observatory. In case of the wind of more than 3rd degree, the most frequent wind direction is NNE followed by NNW, NW and N.

Note) Kaohsiung Weather Observatory is situated to the north of the harbour entrance and on a hill of an altitude of nearly 30m with Shoushan (356m high) behind it.

(4) According to the hourly wind record at Kaohsiung Weather Observatory, the wind in winter of more than 5th degree is scarcely recorded, and strong wind of long duration is mostly from NNE direction. Table-4.5 shows the duration and the maximum speed of strong wind in winter.

(5) The wind characteristics in Kaohsiung due to typhoon are roughly classified into the following categories according to the course of typhoon. The notation used here for each course is different from that of the Observatory.

Course A : Typhoons proceed to NW over South China Sea. Kaohsiung is outside the storm area.

Course B : To NW just south of Kaohsiung. Main wind at Kaohsiung is from SE and sometimes lasts for a long time. West wind is rather rare.

Course C : To NW across Taiwan. Strong wind from NW ~ SW usually lasts for a long time in Kaohsiung.

Course D : To NE through Taiwan Strait. Main wind in Kaohsiung is from SE, and SW wind is relatively weak.

Course E : To NE of the east coast of Taiwan. Strong wind from NW ~ SW sometimes lasts for a long time.

Fig. 4-1

Course of typhoon

(6) Table-4.6 indicates the wind characteristics due to typhoon during 1945 ~ 1963 at Kaohsiung Weather Observatory. The typhoon courses are based on Meteorology Handbook (1959, Japan) for 1945 ~ 1957 and on the data supplied by Taiwan Provincial Weather Bureau for 1958 1963.

Table-4.1 Wind Record at Peng Hu Islands
(from Printed Weather Chart, Meteorological Agency, Japan)

Year 1962 unit: knot

Day	Jan.		Feb.		Mar.		Apr.		May.		June	
	0 h GMT	12 h GMT	0 h GMT	12 h GMT	0 h GMT	13 h GMT	0 h GMT	12 h GMT	0 h GMT	12 h GMT	0 h GMT	12 h GMT
1	N 25	N 20	NNE 25	NNE 25	NNE 20	NNE 30	N 5	S 15	NNE 5	NNE 20	ENE 5	N E 5
2		NNE 20	〃 25	N 15	〃 30	N 30	S 15		〃 5		S 5	S W 5
3	N 10		N 10	N E 20	〃 30	NNE 20	N 20	NNE 25	SSE 10	S W 10	SSW 5	SSW 5
4		NNE 15	〃 20	NNE 25	N 15	N 10	NNE 20	N 15			S 15	S 10
5	NNE 20	N 20	〃 15	〃 10	0	0	N E 10	N E 5	S 20	SSE 10		NNE 15
6	〃 20	NNE 20	NNE 10	〃 10	N 10		〃 10	S 5	NNE 10	NNE 5	NNE 5	〃 5
7		N 15	N 5		S 5	NNE 25	SSW 10			S W 5	S E 5	S E 5
8	N 30	N 25	NNE 10	NNE 10	NNE 20		〃 5		SSE 5	〃 5	W 5	NNE 5
9	〃 25	NNE 20	N 5	NNW 5	E 10	NNE 5	N 15	N 20	NNE 5	N 20	S W 5	〃 15
10	〃 25	NNW 20		S W 5	N W 10	〃 15	〃 30	NNE 30	〃 10	NNE 15	SSE 5	〃 15
11	NNE 10	N 10	W 5	〃 5		N 25	NNE 20	N 10	N E 5	SSW 5		S 5
12	N 10	NNE 10	NNE 20	NNE 20			N 5	〃 10	S W 5	N 5		SSE 15
13	〃 5	〃 15	〃 25	N 30	N 10	WNW 5	〃 20	NNE 35	N 5	N E 5	S W 15	S E 10
14	NNE 10	〃 15	〃 30	N E 25			NNE 20	〃 20	W 15	SSW 10	S 15	〃 10
15	〃 10		〃 25	NNE 25	W 5	N 10	〃 10	〃 5	〃 5	N E 5	〃 5	N 5
16	〃 30	N E 20		〃 20	NNW 5	N E 5	〃 10	〃 10	〃 5	NNE 5	ENE 10	
17	N 20		NNE 20		NNE 20	N 15	〃 5		NNE 10	N E 5	S E 10	S E 5
18	NNE 20	NNE 20	〃 5	N W 5	N 10	NNE 15		NNE 35	SSE 5	NNE 15	〃 10	S 10
19	ENE 20	〃 15	N 5	N E 10	〃 5	E 10	NNE 20	SSW 20		N 30	S 10	
20	N 20	N 20	NNE 20	N 15	S 15	S 10			NNE 25	〃 20	SSW 10	SSE 15
21	NNE 20		N 5		NNE 20	NNE 25		NNE 5	N 25	NNE 20	S 15	SSW 10
22	〃 20	NNE 35	NNW 5	W 5	〃 25	N E 25	N 5	NNW 5	〃 10	〃 10	SSW 5	SSE 15
23	N E 15			N 5	N 30	N 25	WNW 5	SSW 5	〃 5	SSW 5	〃 10	ESE 10
24		NNE 20	NNE 5		〃 25	NNE 20	SSW 5	〃 15		NNE 5	S 15	〃 25
25	NNE 25		N E 10		NNE 10	N 15	N 15	NNE 20	N 15	ENE 10	SSE 10	S 10
26	〃 20	N 5		NNE 25	〃 20	N E 25	NNE 20	N 10	S 10	S 15		〃 10
27	〃 20	N E 25	NNE 20	〃 15	〃 25	N 15	〃 5		〃 20	〃 10	S 15	〃 15
28			〃 20	N 15	〃 5	〃 20	N 20	N 10	SSW 10	〃 15		
29	N 15				〃 30	NNE 50	NNE 15	〃 5	〃 10	N 20	S 10	S 20
30	NNE 5	NNE 35			〃 25	N 15	N 5	N 5	NNE 20	NNE 15	SSW 5	SSW 5
31	〃 30	〃 35			N 15				〃 10	N 10		

* indicates that the observatory is inside typhoon zone.

Day	July		Aug.		Sept.		Oct.		Nov.		Dec.	
	0h GMT	12 h GMT	0h GMT	12 h GMT	0 h GMT	12 h GMT	0 h GMT	12 h GMT	0 h GMT	12 h GMT	0 h GMT	12 h GMT
1	S W 5	S 10	W 5	S 15	S 10	ESE 25		NNE 25	NNE 5	N 5		NNE 20
2	SSE 10	SSE 10	SSE 15		E 10	N W 10	NNE 25	〃 60	N E 5	0		
3	S 5		SSW 10		N W 5	NNE 20	N 20	SSE 20	N 5	NNE 25	NNE 15	NNE 25
4	0	0	N E 5	NNW 10	NNE 25	N* 45	S 20	S 5	NNE 25	N 30	N 30	N 30
5	W 5		N* 30	N* 50		S W*30	NNE 10	NNE 25	〃 30	NNE 20	N E 30	NNE 30
6	SSE 25	SSW 10	S W* 30		S W*25	SSW 10	N E 20	〃 15	N E 15	〃 10		〃 15
7	SSW 10	S W 5	S 10	N W 5			NNE 15	〃 20	〃 5	〃 20	NNE 10	NNW 15
8		S 10	S W 5		E 10		〃 10	〃 5	NNE 15		SSE 15	NNE 15
9	S W 5	SSW 10	NNE 5	NNE 5	ENE 5	N 10	〃 5	〃 5	〃 30	NNE 30	NNE 15	0
10	SSW 10	ENE 5	S E 15	SSW 5	N 5		N 5	N 5	〃 25	N 20	N 10	
11	S E 10	N W 5	S 5	〃 5		NNW 5	〃 5	0	〃 20		〃 10	NNE 20
12	NNW 5	NNW 10	NNW 5	〃 5		W 5	〃 5	0	N 10	NNE 15	NNE 15	〃 15
13	N W 5	S W 5	〃 5			N 5	N E 5	W 5	NNE 15	N E 15	N 15	
14	ESE 5	SSW 5	S W 5			〃 10	WNW 5	NNE 25	〃 15	NNE 25	〃 10	
15	S W 5	N 5	W 5	SSW 10				NNE 30	N 30	〃 30	NNE 10	NNE 30
16	SSW 5		WSW 5	S 5	E 5	W 5	NNW 15	N 15	N E 10	N 20	〃 30	〃 20
17	SSE 5	S 5	N 5		SSW 5	S W 5		〃 20		NNE 25		〃 20
18	S W 10	〃 5	N W 5	N 5	S W 5	N W 5	NNE 10	NNE 25	NNE 20	SSW 20		N 15
19	WSW 10	N W 5		W 5		N 5	〃 20	〃 20	N 10	N 15	ENE 5	〃 10
20	WNW 5	SSW 5	SSW 5	S 5		NNW 5	〃 25	〃 30	〃 10	〃 15		NNE 25
21	NNE 5	S W 10	W 5	S W 5	N 10			〃 25	NNE 20	N E 30	NNE 15	〃 25
22	〃* 20	N* 25	S W 5	SSW 5	SSW 5		NNE 25	N 25	N 25	N 25	N 20	SSW 10
23	WSW* 10	SSW* 25	W 5	N 5	S E 5		〃 5	NNE 20		〃 25		
24	SSW 15	SSW 20		S W 10	SSW 5	N W 5	〃 25	〃 25		〃 15	N 10	NNE 15
25	SSE 15		NNE 5	〃 5	NNW 5	NNE 15	N E 20	〃 35	N W 10	NNE 5	〃 25	〃 10
26	S E 5	W 5	SSW 5	S 10	NNE 15	〃 25			N 15			N 5
27	N 5	NNE 5		〃 5	NNW 5	〃 20	NNE 35		NNE 30	NNE 35	W 5	S W 5
28	NNW 5	N 10	SSW 10	〃 10	N 25	N 20			〃 30	NNE 30	NNE 5	NNE 10
29	N 10	N E 15	S 5	NNE 10			NNE 15	NNE 15	〃 30	ENE 10	〃 5	N 10
30		NNE 15	NNE 15	〃 30	NNE 25	N 25	N 15	〃 15	〃 25	NNE 30	N 15	〃 20
31	N E 15	N 25	S 10				NNE 10	〃 20	〃		NNE 30	

(2) Year 1963

Day	Jan. 0h GMT	Jan. 12h GMT	Feb. 0h GMT	Feb. 12h GMT	Mar. 0h GMT	Mar. 12h GMT	Apr. 0h GMT	Apr. 12h GMT	May. 0h GMT	May. 12h GMT	June 0h GMT	June 12h GMT
1	NNE 15	NNE 15	NNE 10	NNE 20	N 5	NNW 5		N 5	0		W 5	WNW 10
2	〃 15	〃 20	〃 15	〃 5	NNW 5	SSW 5	N 10	NNE 20	N E 15	N E 15	S W 10	
3		〃 10		〃 20	N W 5	0	〃 10	N 5		ENE 5	SSW 10	
4			NNE 25	〃 25	NNE 10	NNE 15	〃 5	0	S 10	0	〃 15	ESE 5
5		N 25	〃 20		〃 5	N 10	SSW 5	SSW 10	0	N 5	S E 5	NNE 10
6	N 25	NNE 25	〃 5	N 15	〃 15		WSW 10	NNW 5	SSW 5	0	NNE 10	〃 15
7	NNE 25	〃 20	NNW 5	〃 5	N 20	NNE 15	N 20	N 25	ENE 10	SSW 5	N 25	〃 25
8	〃 20	〃 15			S W 5	〃 5	〃 25		SSW 10	S W 5	〃 30	
9	〃 15	〃 20			E 10	0	〃 30	NNE 20	S W 5		NNE 20	NNE 20
10	〃 20	〃 30	0		NNE 5	NNE 15	NNE 10	NNW 20	SSW 5	S 10	N 5	
11		〃 25	NNE 20	NNE 25	0	〃 20	N 5	NNE 10	〃 10		〃 15	NNE 5
12	N 30	〃 30		〃 30		N 30	〃 10	〃 5	S 5	WSW 5	N E 5	〃 5
13	NNE 30		NNE 30	〃 30	N 20	NNE 25	ENE 5	ENE 5		W 5	S E 10	N E 10
14	〃 25	NNE 20	N 25	〃 10	NNE 20	〃 15	SSW 20	SSE 5		S W 5	ENE 10	〃 5
15		〃 20	〃 10		〃 10	〃 15	0	S 5	S 10	〃 15		N 5
16	NNE 15	N 15	NNE 20	NNE 15			SSE 5	N W 5	〃 10	〃 10	N E 10	〃 10
17	〃 15	NNE 10	〃 25	N 20	N 15	N 15		S		SSW 5		NNE 15
18	N 10	N 5	〃 25	N E 20	〃 5	NNE 5	S 10	SSW 5	WSW 5	〃 5	NNE 20	〃 20
19	NNE 10	NNE 10	〃 15	NNE 10	S E 5	N 5		〃 5	S W 5	〃 5	WSW 10	S W 5
20		N 5		〃 20		NNW 5	S E 5	WSW 5	SSW 10		0	NNE 5
21	NNE 30	NNE 25	NNE 25	〃 25	N 5	NNE 10					N E 5	N E 5
22	〃 15	N E 20				N E 5	N E 5	W 5	S 5	WSW 55	〃 5	ENE 5
23	〃 20	NNE 25	NNE 10		N 10	〃 20	〃 5	N W 5	SSW 5	N W 5	S W 5	S 5
24	〃 15	0	〃 10	NNE 20	NNE 25	NNE 25	N 5	NNE 15	N W 10	NNW 5	S 10	SSE 20
25	N 15	NNE 20	N 10	〃 5	〃 10	N 10		〃 20	N 10	N E 10	〃 10	W 10
26		〃 10	NNE 20	〃 15	〃 10	NNE 15	N E 20	N 15	W 5	W 5	S W 5	
27	N 10	〃 15	〃 20	〃 10	〃 5	N 5	NNE 15		S 5	N 5	W 10	WNW 10
28		〃 5	〃 10			NNE 30	N W 5	WSW 5	0	W 5	N 5	N E 5
29	NNE 5	N 5			N 25	〃 20	S W 10	S 5	N W 5		N 10	NNE 5
30	〃 15	NNE 20			N E 10	WNW 5	W 5	WNW 5	S W 10	SSW 10		E 10
31	〃 20	〃 5			S W 5	0			S 10	〃 5		

* indicates that the observatory is inside typhoon zone.

Day	July 0h GMT	July 12h GMT	Aug. 0h GMT	Aug. 12h GMT	Sept. 0h GMT	Sept. 12h GMT	Oct. 0h GMT	Oct. 12h GMT	Nov. 0h GMT	Nov. 12h GMT	Dec. 0h GMT	Dec. 12h GMT
1	S E 15	S 10	N E 5	N 5	S W 10	S W 5			N E 20	NNE 15	N 30	NNE 15
2	S 15		〃 5	〃 10	S 5	W 5			NNE 10	〃 10	NNE 20	
3		S W 10	〃 5	N E 5	W 5	NNE 5	資		N 10	N 5	〃 20	
4	N W 5	S 5	W 5	S W 5	N 10	〃 20			N E 10	NNE 10	N E 20	
5	W 5	〃 5	N W 5	SSW 5	NNE 25	S E 15	料			〃 15	NNE 10	NNE 10
6	S 10	S W 10	SSE 5	S W 5	N 10	N 10				W 5		〃 5
7	S 5	〃 10	S 5	SSW 5	W 10	S E 10	欠		N 5	NNW 5		〃 10
8	〃 10	SSW 10	E 10	SSE 5	N 10	NNE 10			NNE 5	NNE 10	NNE 20	〃 25
9	〃 10	〃 10	SSE 5	S E 5	NNE 20				N E 5	〃 20	〃 20	〃 20
10	〃 10	S 10	〃 10	S W 5		NNE* 20			NNE 15	〃 10		〃 30
11	〃 10	〃 5	SSW 5	SSW 5	WNW* 25	W* 5			0	〃 15	NNE 25	〃 30
12	SSE 10	〃 5	〃 5	S 10	W 10	WSW 15			NNE 10	N 10	〃 30	
13	S E 5	N W 5	〃 10	SSW 15		W 20			〃 15	NNE 15	〃 20	N 10
14	NNE 5	NNW 5	S W 10	0	SSW 15	S 5			〃 10			NNE 10
15		N 15	ENE 5	SSW 5					〃 10	NNE 20		
16	N* 30	SSW* 20		〃 5	S 10	S 5	N 10	NNE 25		〃 20	NNE 15	
17		S 20	SSE 10	〃 5	SSE 5	〃 5		〃 30	NNE 20	〃 15	〃 20	NNE 20
18	S 15		SSW 10	S W 5		〃 5	N E 25	〃 20	N 5	N 5	〃 35	
19	E 20	S 10	〃 10	SSW 5	S E 5	0	N 10	N 5	NNE 10	N E 5	〃 25	NNE 25
20	N E 5	NNE 10	S 5	S W 5	N 5		N E 20	NNE 20	〃 15	NNE 10	〃 20	〃 20
21	0	N 5		S 10			NNE 25	〃 20	〃 15	〃 15	〃 20	〃 20
22	N E 5			W 10	0		N E 5	〃 20	〃 15	0	E 10	N 5
23		S W 5		0	NNE 15	N 20	〃 5	N 20	〃 15	NNE 15	NNE 10	NNE 5
24		WSW 5	W 5	SSW 5	〃 10	N E 10	NNE 5	NNE 15	0		E 15	
25	W 5	S W 5	〃 5	〃 5		NNE 15		N E 20	NNE 20	N E 25	NNE 10	NNE 20
26	〃 5	〃 10	S W 5	NNW 5	NNE 20	〃 15	N E 10	NNE 25	〃 25	〃 30	〃 20	〃 30
27	S W 5	〃 5	NNW 5	NNE 5	〃 5	〃 15	N 10	〃 10	〃 20	〃 15	〃 25	〃 25
28	W 5	〃 5		W 5	〃 15	〃 10	NNE 20	〃 15	N E 15		〃 20	〃 15
29	0		WNW 5	WSW 5		〃 5	〃 20	〃 10	NNE 25	NNE 20		
30	0	S W 5	S W 10	〃 10	NNE 5	N 5	〃 20	〃 20	〃 30	N 20	NNE 10	NNE 30
31	ENE 5	SSW 5		0							〃 10	〃 15

Table-4.2 Most Frequent Wind Direction and Mean Wind Speed in Taiwan
(from Taiwan & Nansei Shyto Pilot, 1962, Hydrographic Department, Maritime Safety Agency, Japan)

Month	Keelung	Hsinchu	Peng Hu	Tainan	Kaohsiung	Hengchun	Tawu	Taitung	Hsinchiang	Hwalien
Jan.	NE 4.4	NE 3.5	NNE 8.7	N 3.9	NW 3.0	NE 5.3	NNE 4.7	NNW 3.6	NNE 4.9	NNE 2.9
Feb.	NE 4.3	NE 3.2	NNE 8.1	N 3.9	NW 3.0	NE 4.7	NNE 4.5	NNW 3.6	NNE 4.6	NNE 2.7
Mar.	NE 3.9	NE 2.6	NNE 6.9	N 3.5	NW 2.7	NE 4.5	NNE 3.4	NNW 3.0	NNE 3.8	NNE 2.7
Apr.	NE 3.1	NE 2.4	NNE 5.4	N 2.9	NW 2.5	NE 3.6	NNE 3 3	NNW 2.8	NNE 3.5	NNE 2.4
May.	E 2.7	NE 2.2	NNE 4.5	NNE 2.5	NW 2.4	NE 2.8	NNE 2.6	NW 2.4	NNE 3.0	SW 2.0
June	SSW 2.7	SW 2.7	S 4.2	SE 2.6	NW 2.5	W 2.7	W 2.3	NW 2.3	NW 2.8	SW 2.0
July	SSW 3.0	SW 2.4	S 3.9	SE 2.7	NW 2.9	E 2.8	W 2.5	NW 2.4	NW 3.3	SW 2.3
Aug.	SSW 3.2	SW 2.3	SSW 4.1	SE 2.6	NW 2.9	NW 2.9	W 2.4	NW 2.4	NW 2.7	SW 2.1
Sept.	E 3.7	NE 2.4	NNE 5.4	N 2.5	NW 2.4	NE 3.1	NNE 3.1	NNW 2.7	NW 3.3	SW 2.1
Oct.	NE 3.9	NE 3.4	NNE 8.4	N 2.7	NW 2.2	NE 4.8	NNE 4.5	NNW 3.4	NNE 4.6	NNE 2.5
Nov.	NE 4.6	NE 3.7	NNE 9.1	N 3.1	NW 2.4	NE 6.0	NNE 4.8	NNW 3.6	NNE 4.4	NNE 2.7
Dec.	NE 4.5	NE 4.1	NNE 9.2	N 3.6	NW 2.7	NE 6.1	NNE 5.0	NNW 3.7	NNE 5.2	NNE 2.9
Year	NE 3.7	NE 3.0	NNE 6.5	N 3.0	NW 2.6	NE 4.1	NNE 3.6	NNW 3.0	NNE 3.8	SW 2.4
Period	1902 ~ 15	1938 ~ 44	1897 ~ 44	1897 ~ 44	1932 ~ 43	1897 ~ 44	1942 ~ 44	1901 ~ 44	1941 ~ 44	1921 ~ 44

Table-4.3 Wind Record at Kaohsiung

(from Japan Waterway Directory Vol.6, 1914)

Month	Most frequent wind direction	Mean wind speed	Storm direction	Storm wind speed	Stormy days
Jan.	NW	4	—	—	0
Feb.	NW	3	—	—	0
Mar.	NW	3	—	—	0
Apr.	NW	2	—	—	0
May.	NW	2	—	—	4
June	ENE	2	—	—	2
July	ENE	3	SE	6	10
Aug.	NW	3	NW	6	13
Sept.	NW	2	SE	6	16
Oct.	NW	2	—	—	9
Nov.	NW	3	—	—	2
Dec.	NW	3	—	—	0
Year	NW	3	—	—	56

The storm in the table means the wind of more than 10 m/sec.

Based on the observation at the Kaohsiung lighthouse from 1903 to 1916.

Table-4.4 Wind Record at Kaohsiung Weather Observatory

Wind force (Wind speed) Wind direction	3 (3.4~5.4)	4 (5.5~7.9)	5 (8.0~10.7)	6 (10.8~13.8)	7 (13.9~17.1)	8 (17.2~20.7)	9 (20.8~24.4)	10 (24.5~28.4)	total	mean	%
N	123 113 85	73 59 56	18 19 27	0 12 4	0 0 1				215 203 173	197	10.23
NNE	113 189 275	43 147 189	10 38 59	0 5 4	0 2 1				166 381 528	358	18.60
NE	30 68 60	4 5 14	1 1						35 74 74	61	3.17
ENE	82 76 71	10 10 5	3 1	1	1				96 88 76	87	4.52
E	41 54 31	46 15	15	3	3				108 69 31	70	3.63
ESE	86 61 41	129 36 13	44 9 6	9 1	2	3 1			273 108 60	147	7.67
SE	59 46 35	41 32 21	15 16 19	0 7 9	0 6 0	1	1	1	115 110 84	103	5.35
SSE	37 36 107	14 35 110	4 8 36	9 13	2 1	2			55 92 261	136	7 06
S	8 16 89	12 13 48	3 4 11	1					23 34 142	66	3.43
SSW	16 12 122	2 7 28	1 1 4	1					20 20 154	65	3 37
SW	26 11 16	4 10 6	2 1	3 1		1			35 24 22	27	1.40
WSW	29 23 39	9 7 19	1 2 9	1 2	2 1	3			42 38 67	49	2.54
W	17 22 54	8 2 9	1 5	3 2	2 1 1				28 28 71	42	2.18
WNW	8 34 106	4 7	2 3	2 3	6 1	2 2	2 1	4	8 56 123	62	3.22
NW	198 186 149	30 26 22	4 2 18	7 3	3				232 224 192	216	11.22
NNW	91 203 286	44 43 29	9 7 6	3 1 1	1				147 255 316	239	12.41
Total	964 1,150 1,548	469 451 576	131 111 203	21 52 39	10 22 5	3 10 2	3 1	5	1,598 1,804 2,374		100
Mean	1,221	499	145	37	12	5	1	2	1,925		
%	(13.94)	(5.69)	(1.69)	(0.42)	(0.14)	(0.06)	(0.01)	(0.02)	(21.97)		

under the wind force of 2 1961: 7162 times
1962: 6956
1963: 6386
Mean: 6835

% in ( ) corresponds to 365 x 24 = 8760

Three lines in the columns correspond to 1961, 1962 and 1963, respectively.

Table-4.5 Strong Wind in Winter at Kaohsiung

(Kaohsiung Weather Observatory, 1961 ~ 1963)

Date	Main wind direction	Duration	Max. wind speed
1961 1 - 23	SE	6 hr	10 m/s
2 - 5	ESE	7	11
1962 - 1 - 1 ~ 2	N	5	10
1 - 23	NNE	8	15
1 - 26 ~ 27	N ~ NNE	16	13
12 - 2	NNE	5	10
1963 - 1 - 5	NNE	6	11
1 - 6	NNE	7	10
1 - 7	NNE	16	11
1 - 15	NNE	11	15
1 - 25	NNE	8	10
2 - 26	NNE	7	14
12 - 4	N	7	11

Table-4.6 Wind at Kaohsiung due to Typhoon

(wind speed and direction : Kaohsiung Weather Observatory,

typhoon course : Meteorology Handbook and Taiwan Provincial Weather Bureau)

Date	no.	Course	Max. speed & direction (m/s)	Main direction & duration of more than 10 m/sec
1945. 9. 2	⑭	C	NW 24	No records except at 6, 14 and 22h
9.11	⑮	C	SSW 10	
10. 1	⑱	D	E 28	
1946. 3. 6	①	E	NW 13	
6.22	③	C	WSW, SW 10	
7.11	⑥	C	SSW 9	
7.17	⑦	B	ESE 17	
9.26	⑲	C	SSW 6	
10.14	㉑	A	NNE 3	
1947. 6.22	③	D	ESE 23	
7.29	⑥	E	W 11	
8.29	⑧	B	SE 10	
10. 2	⑫	B	ENE 9	
10. 8	⑭	D	E 20	
12.27	㉒	E	NE 11	
1948. 6. 6	⑥	C	W 3	
6. 8	⑤	B	ESE 18	ESE 2
7. 3	④	逆E	WNW 4	
8.21	⑮	C	SSE 5	
9.18	㉒	C	WSW 13	NW~WSW 6
10. 6	⑲	C	SSW 4	
12.12	㉟	E	W 4	
1949. 7.28	⑦	E	WNW 16	WNW~WSW 7
9. 6	⑬	B	SE 13	SE~ESE 3
9.15	⑭	C	SE 19	SE 12
9.30	⑯	C	WNW 6	
10. 4	⑰	D	ESE 24	E~SE 20
12.13	㉔	E	WNW 7	
1950. 6. 6	④	D	S 13	SSE 11
1951. 4. 8	④	E	WNW 3	
8.13	⑩	B	SE 13	SE 3
9.26	⑭	D	SE 16	SE 22
1952. 6.15	①	D	S 8	SE 21
6.22	②	E	W 16	W 8
7.18	⑤	C	WSW 17	WSW 18
7.29	⑥	B	SE 26	SE 21
9. 1	⑪	D	S 17	S 4
11.14	㉑	D	NE 12	NW, NE, SE 5
11.27	㉓	D	SE 18	SE~SW 8
1953. 6. 5	②	E	NW 9	
6.28	③	B		
7. 4	④	C	NW 22	NNW16, SW~SE 12
8.16	⑦	C	W 18	WNW 8, WSW 15
8.21	⑨	C	SSE 17	SSE 4
9. 1	⑩	B	ENE 28	SE 24
10. 3	⑯	E	ESE 11	ESE 1
1954. 8.29	⑧	B	ESE 11	ESE 3
9.24	⑮	E	N 3	
11. 5	⑲	A	E 4	
11.11	⑳	A		

Date	no.	Course	Max. speed & direction (m/s)	Main direction & duration of more than 10 m/sec
1955. 7.12	⑧	E	NNW 6	
8.23	⑲	C	NNW 12	NNW, SW 6
9.25	㉑	A	E 5	
1956. 4.23	③	E		
8. 1	⑥	C	NNW 8	
9. 3	⑪	C		
9.17	⑬	C	WSW 18	SW 9, SE 8
9.22	⑭	B	SE 23	NNW~SW 5, SE10
1957. 6.25	⑤	C	W 17	WNW 19
7.16	⑥	B	ESE 16	ESE 19
9.14	⑪	B	ESE 21	ESE 15
1958. 7.16		C	W 18	W 6, E 4
8.30		C	ESE 12	ESE 6
1959. 3.15		C		
7. 6		A	ESE 11	ESE 2
8. 7		NE Across Taiwan	WSW 19	WSW 22
8.23		B	E 31	E~SE over 7
8.30		C		
10. 9		E		
1960. 4.25		E	SSE 5	
6.10		D	SSE 10	
8. 1		C	W 15	WSW over 8
8. 8		C	NW 9	
8.14		C	NNW 4	
8.23		E~C		W 11, SSW 3
1961. 5.29		D	E 12	ESE 3
6. 8		C	SE 9	
6.27		C	WSW 4	
7. 1		B	ESE 9	
7.14		C	ENE 15	ESE 10
7.19		A	E 10	E 3
8.25		C	W 15	NNW~SW 6
9. 8		A	ESE 7	
9.12		C	WSW 17	WSW 5
9.29		C	ESE 19	ESE 16
1962. 7.22		E~C	SW 18	NW 14, WSW 5
8. 6		C	WSW 18	NW~WSW 10
8.31		B	SE 16	SE 25
9. 5		C	WNW 28	W 17
10. 3		B	SE 26	SE 16
1963. 6.30		B	SSE 13	SSE 25
7.16		C	WNW 24	WSW 13
9.11		C	WNW 15	WNW 5

3. Wave

3.1 Wave characteristics along the west coast of Taiwan

(1) Wave characteristics are different in the north and south regions according to the direction of the shoreline of the west coast of Taiwan.

(2) Monsoon-generated waves in winter directly attack the northern coast, whereas have little influence on the southern coast, where wind waves or swells due to typhoon in summer are prominent.

(3) In the opinion of Prof. Tang, Cheng Kung University, the wind waves in Taiwan Strait generated by the winter monsoon have a fetch extending at most as far as the mouth of the Yangtzu-kiang, and the wave height is limited by the width of wind zone and water depth in the fetch.

(4) Table-4.7 is the wave record observed at Taichung Harbour which is in the northern region (from Report on the Model Study for Taichung Harbour, 1963, The Tainan Hydraulic Laboratory).

(5) Table-4.8 is the wave record observed at Hsinta Harbour (from Report on the Tidal Inlet Improvement in Hsinta Harbour, unpublished).

3.2 Wave characteristics in the vicinity of Kaohsiung

(1) The wind waves in Taiwan Strait generated by NNE monsoon in winter have no direct influence on the coast near Kaohsiung owing to the direction of the shoreline and the existence of Peng Hu Islands. Only their refracted and diffracted waves reach the coast together with the local wind waves whose fetch stretches up to Peng Hu Islands. These waves are not so big as to affect the stability of structures or navigation of ships around the harbour.

(2) Local wind waves due to monsoon or land and sea breezes in summer are almost out of the question.

(3) In case Kaohsiung District is inside the storm area of typhoon, fairly big waves naturally attack the coast. Swells also arrive when typhoon is passing over South China Sea, even when Kaohsiung is outside the immediate storm area.

(4) Table-4.9 is the wave record by eye-observation at Kaohsiung Weather Observatory. Although the details of its observing method are unknown and the absolute value of the recorded wave height can not be readily acceptable as it is from the engineering point of view, valuable informations will be obtained by a careful study of these data, comparing

them with meteorological conditions.

(5) Table-4.10 illustrates the monthly frequency of wave degree during 10 years based on the above-mentioned wave record. It is clearly seen that big waves concentrate in the typhoon season.

(6) Table-4.11 shows the meteorological conditions for the cases where the recorded wave degree is more than 4 or where any typhoon is found nearby. The relation between wave characteristics and meteorological conditions is expected to be made clearer by getting such data from weather charts as the range of storm area, existence of tropical depressions, atmospheric pressure distribution of winter monsoon, etc.

(7) Refering to the above table, the relation between waves and typhoon courses is presumed as follows:-

Course A : As Kaohsiung is outside the typhoon, and nothing but swells will be observed. There will be little influence when the typhoon is heading for Hainan Island and southward.

Course B : Under strong SE wind, swells as well as wind waves will be observed.

Course C : Under strong W wind, big wind waves will be observed. Waves from SW will be prominent.

Course D : Similar to Course B but with a smaller scale.

Course E : Similar to Course C but with a smaller scale.

(8) The biggest wave reaching Kaohsiung seems to be observed when a big typhoon passes the Course C. However, it should be further studied whether this course has a distinctive effect compared with other typhoon courses.

(9) Definite dimensions of the design wave should be determined by both the future wave observation and the wave hindcasting from the meteorological data. Namely, the hindcasting method is applied to the typhoon models, of which the scale and the couse are considered to give the worst condition to Kaohsiung coast, after the accuracy of the method having been identified by actually observed records.

Table-4.7 Wave Record at Taichung Harbour

(Pressure-type direct recording wave-height meter, from Report on the Model Test for Taichung Harbour, Tainan Hydraulic Laboratory, 1962)

(1) Waves in winter

Date hr	Wind direction	Wind speed	T ⅓	H ⅓
		m/s	sec	m
1959-2-17-19	ENE	4.0	6.5	0.39
21	NNE	9.9	5.2	0.48
23	〃	6.8	5.5	0.60
18- 1	〃	8.3	6.3	0.59
3	N	2.5	5.3	0.41
5	NNE	6.9	5.3	0.42
22-10	N E	7.0	7.9	0.95
12	〃	7.6	7.1	0.87
14	〃	9.6	7.1	1.50
16	〃	9.9	7.3	1.17
18	〃	8.7	6.9	1.34
20	〃	9.6	6.7	1.15
22	NNE	8.2	7.2	1.12
23- 0	N E	7.0	7.5	1.37
2	〃	9.4	7.8	1.70
4	NNE	15.4	8.3	2.33
6	〃	13.6	8.6	2.03
8	N E	11.1	8.5	2.07
10	〃	8.9	7.3	1.09
12	〃	6.3	8.0	0.91
14	NNE	8.0	7.2	0.95
16	〃	7.2	7.2	0.95
18	〃	11.0	6.7	1.28
20	〃	13.6	7.4	1.67
22	〃	13.2	9.2	1.22
24- 0	〃	13.2	8.1	1.11
2	〃	11.2	7.6	1.40
4	〃	9.9	7.3	1.35
6	〃	15.7	7.1	1.76
8	〃	14.7	7.6	1.54
10	〃	15.1	8.1	1.15
12	〃	15.0	6.6	0.81
14	〃	12.9	6.6	1.09
16	〃	15.0	6.0	1.40
18	〃	12.1	7.0	1.23
20	〃	13.2	7.7	1.15
22	〃	11.2	7.4	0.75
25- 0	N E	5.5	7.1	0.57
2	NNE	7.7	6.5	0.71
4	〃	11.4	6.7	1.27
6	〃	12.1	7.5	1.38
8	〃	9.5	7.2	1.16
10	〃	7.5	6.6	0.85
12	〃	9.9	6.6	0.33

Date hr	Wind direction	Wind speed	T ⅓	H ⅓
		m/s	sec	m
1959-2-27-18	NNE	11.7	7.0	0.82
20	〃	13.5	7.9	1.36
22	〃	13.9	6.0	0.78
28- 8	〃	9.5	6.1	1.19
3-9-13	〃	15.0	6.5	1.02
15	〃	13.6	8.2	1.05
17	〃	17.2	7.1	1.43
19	〃	12.0	7.5	0.97
21	〃	11.0	6.8	0.78
23	〃	14.2	7.0	0.95
10- 1	〃	15.7	7.0	0.83
3	〃	15.7	7.5	0.80
5	〃	16.6	7.5	0.86
7	〃	15.1	5.4	0.72
9	〃	15.8	5.5	0.90
11	〃	10.7	6.8	0.36
13	〃	12.7	5.6	0.46
15	〃	14.4	5.5	0.58
17	〃	8.7	5.4	0.51
19	〃	12.1	6.2	0.83
21	〃	10.5	6.7	0.53
23	〃	7.5	5.3	0.44
11- 1	〃	6.2	5.1	0.65
3	〃	7.2	6.7	0.47
5	〃	6.8	6.5	0.53
7	〃	6.1	6.0	0.67
9	〃	4.7	7.4	0.88
14-15	〃	11.0	8.4	1.44
17	〃	12.9	8.5	1.48
19	〃	14.2	7.3	1.44
21	〃	15.1	8.3	1.39
23	〃	12.4	8.3	1.52
15- 1	〃	15.7	7.7	1.12
3	〃	12.9	7.5	1.37
5	〃	13.6	8.2	1.30
7	〃	11.7	8.4	1.34
9	〃	17.3	8.2	1.26
11	〃	16.6	8.5	1.36
13	〃	18.4	7.7	1.29
15	〃	16.9	8.5	1.37
17	〃	16.9	8.0	1.78
19	〃	15.4	8.5	1.47
21	〃	16.9	8.9	1.22
23	〃	15.8	8.0	1.02
16- 1	〃	15.4	8.7	1.02

Date hr	Wind direction	Wind speed	T⅓	H⅓
		m/s	sec	m
1960-1-11-12	NNE	20.9	5.4	0.90
14	〃	26.6	5.7	0.89
16	〃	24.7	6.0	1.08
18	〃	10.2	6.0	0.97
20	〃	9.5	6.6	0.71
22	〃	4.6	7.9	0.76
12- 0	C	0	6.6	0.62
2	NNE	3.1	6.6	0.55
4	C	0	6.5	0.45
6	〃	0	6.8	0.37
8	〃	0	6.0	0.38
12	WNW	0.8	5.7	0.38
14	N	4.4	6.0	0.56
16	〃	5.5	5.9	0.56
18	NNE	5.0	5.2	0.55
20	N	2.8	5.1	0.43
16-12	NNE	15.4	8.5	0.52
14	〃	15.0	7.8	1.02
16	〃	16.4	7.3	1.10
2-15-16	〃	15.8	7.0	0.88

(2) Waves in summer

Date hr	Wind direction	Wind speed	T⅓	H⅓
		m/s	sec	m
1959-8-23- 2	SSW	9.3	5.2	1.20
4	〃	6.1	5.8	1.30
6	S	1.3	5.4	1.24
8	〃	1.0	5.9	0.82
10	〃	3.3	5.7	0.99
12	S W	2.5	6.2	1.15
14	N W	4.2	3.4	1.03
16	W	3.3	5.3	0.99
18	E	3.0	6.2	0.95
20	ENE	2.0	5.6	0.69
22	NNE	4.3	4.6	0.52
		m/s	sec	m
1960-7- 7-13	WSW	7.3	4.9	1.32
15	S W	7.8	5.3	1.30
17	〃	8.3	6.0	1.17
19	〃	5.7	6.3	1.21
21	SSW	6.0	5.9	0.72
23	〃	5.5	5.3	0.74
8- 1	〃	4.8	5.2	0.53
3	〃	4.8	5.7	0.56
5	〃	5.5	5.6	0.89
7	〃	6.9	5.3	0.99
9	〃	7.1	5.9	0.80
30-19	S	3.3	5.9	0.81
21	C	0	6.0	0.55
23	S	1.2	5.5	0.38
31- 9	NNE	12.0	5.4	0.63
11	〃	11.2	6.0	0.93
13	〃	21.8	6.1	1.11
21	NNW	14.7	6.9	2.31
23	〃	14.0	8.0	2.27
8- 1- 1	〃	9.7	7.5	1.80
9	WSW	16.7	7.2	2.85

Note) The typhoon on 31 July and 1 Aug 1960, took Course C.

Table-4.8 Wave Record at Hsinta Harbour

(from Report on the Tidal Inlet Improvement in Hsinta Harbour)

Instrument : pressure-type direct recording wave-height meter

Water depth : about 7m

Wind direction and speed: from weather charts

Date	Wind direction, wind speed	$T_{1/3}$	T max	$H_{1/3}$	H max
Result of the 1st observation					
1964-7-7-09	S W 5 m/s	4. 6 s	10. 5 s	0. 7 m	2. 0 m
11	〃	4. 3	11. 0	0. 5	1. 4
13	〃	4. 1	12. 0	0. 6	1. 7
15	〃	3. 9	12. 5	0. 6	2. 0
17	〃	3. 9	11. 0	0. 6	1. 6
19	〃	4. 5	16. 0	0. 4	0. 7
21	〃	4. 2	14. 5	0. 4	0. 9
23	〃	4. 0	15. 0	0. 6	1. 6
8-01	〃	4. 7	13. 0	0. 3	1. 4
03	〃	4. 3	13. 0	0. 4	1. 6
05	〃	4. 2	15. 0	0. 4	1. 2
07	〃	4. 0	10. 5	0. 5	1. 2
09	〃	4. 0	10. 0	0. 6	1. 3
Result of the 2nd observation					
1964-8-8-02	SSE 16 m/s	10. 7 s	18. 5 s	4. 0 m	5. 0 m

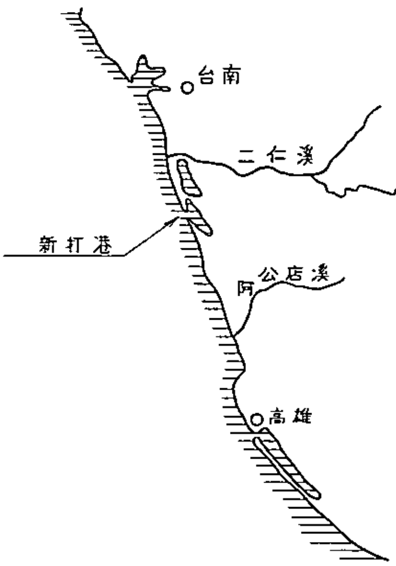


Fig. 4-2 Hsinta Harbour

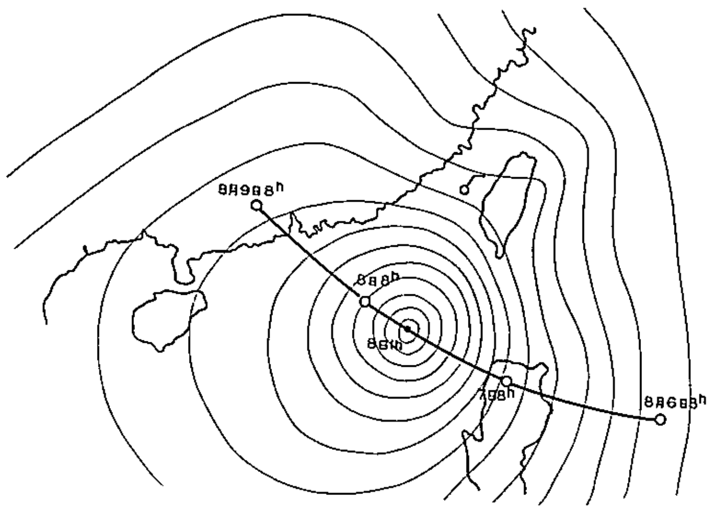


Fig. 4-3 Cource of Taiphoon (Experienced Aug. 1964)

Table-4.9 Wave Record by Eye-observation

(Kaohsiung Weather Observatory)

1. Wave degree

wave degree	wave height
0	0.25 m
1	0.25 ~ 0.75
2	0.75 ~ 1.25
3	1.25 ~ 1.75
4	1.75 ~ 2.25
5	2.25 ~ 2.75
6	2.75 ~ 3.25
7	3.25 ~ 3.75
8	3.75 ~ 4.25
9	4.25 ~ 4.75

2. Typhoon number

Figures marked as 200, 201 etc. stand for the typhoon number at the observatory.

3. Typhoon course

A :	West or northwestward through or off the north of Taiwan
B :	West or northwestward through the middle of Taiwan
C :	West or northwestward through or off the south of Taiwan
D :	Northward through or off the east of Taiwan
E :	Northward through the west of Taiwan or Taiwan Strait
F :	Northeastward through or off the south of Taiwan
G :	Unusual

Year 1952

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
1				1	1	2	2	2	4(202 E)	1	2	1
2				1	1	3	1	2	3	1	2	2
3				1	2	3	2	3	2	1	2	1
4				3	2	3	2	3	3	1	2	4
5				1	1	2	2	2	3	2	1	1
6				1	1	2	4	2	2	1	3	2
7				1	2	2	4	2	2	1	1	2
8				2	1	1	4	3	2	2	2	3
9				2	2	2	2	2	2	2	2	3
10				1	2	2	2	2	2	1	2	3
11				1	1	2	2	2	4	4	2	2
12				3	1	3	2	2	5	2	2	2
13				2	1	3	2	2	2	2	4(203 E)	2
14				2	1	4	2	2	2	2	3	2
15				2	1	3	1	2	1	2	2	1
16				1	1	2	3	2	2	2	2	1
17				2	2	1	5	2	1	2	2	2
18				1	1	2	7(201 A)	2	1	2	3	2
19				1	3	3	4	2	1	2	2	3
20				1	2	3	2	2	2	2	2	2
21				1	3	5(200 D)	3	2	2	2	1	2
22				1	3	2	3	1	1	2	1	2
23				2	1	1	3	2	1	2	2	3
24				3	1	2	5	2	2	3	2	3
25				2	1	2	3	2	2	2	2	2
26				1	2	2	2	1	1	2	3	2
27				2	2	2	1	2	1	1	4(204 E)	3
28				3	2	4	1	2	2	3	3	2
29				2	1	4	5	2	2	2	2	3
30				1	2	3	4	2	1	3	2	2
31					2		3	2		4		3

Year 1953

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	1	2	2	2	2	1	3	1	6	2	1	1
2	1	3	2	2	2	1	3	1	4(209 F)	1	1	2
3	3	2	3	2	2	1	5	1	3	3	2	1
4	3	2	2	1	2	1	6(206 B)	1	2	2	2	1
5	1	2	3	2	1	2	5	1	2	2	2	1
6	2	3	2	2	1	5(205 D)	2	1	2	2	1	3
7	3	1	2	3	1	5	1	1	2	2	2	2
8	1	2	2	2	2	2	1	2	2	2	1	2
9	2	3	2	2	2	1	1	2	2	1	1	3
10	2	3	2	2	1	1	1	2	2	1	2	2
11	3	1	2	1	3	2	1	2	2	2	1	2
12	2	1	2	2	2	2	2	2	2	1	2	1
13	1	1	1	2	2	2	2	3	1	1	2	1
14	3	2	2	1	2	3	2	3	2	1	2	2
15	3	2	3	1	2	2	2	3	2	1	3	2
16	3	2	3	2	2	1	2	5(207 A)	2	1	2	2
17	3	2	1	2	2	2	2	5	2	2	2	1
18	2	2	3	2	2	2	1	5	2	2	4	1
19	2	2	2	2	2	1	2	5	1	2	1	2
20	2	2	2	2	1	1	2	4(208 B)	1	2	1	2
21	2	3	2	2	1	1	1	4	2	2	1	3
22	2	2	3	2	2	2	1	3	2	1	2	1
23	3	2	3	1	2	2	2	3	2	2	1	1
24	1	2	1	2	1	2	3	3	2	2	1	2
25	1	1	2	2	2	1	1	3	2	1	2	2
26	1	2	2	1	1	1	1	2	2	1	2	2
27	2	1	1	1	4	3	1	1	2	2	1	2
28	2	2	1	2	4	3	1	2	2	1	2	2
29	2		1	1	2	3	1	2	2	1	2	1
30	2		1	1	3	4	1	2	2	1	1	1
31	4		1		2		1	2		1		1

Year 1954

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	1	1	2	1	1	1	2	1	2	1	1	2
2	1	2	3	1	1	2	4	2	2	2	1	1
3	2	2	1	1	2	2	3	1	2	2	1	2
4	3	2	3	1	2	3	3	1	2	1	1	1
5	2	3	2	3	1	1	1	3	2	1	2(212 C)	1
6	2	1	2	2	3	1	3	3	2	2	3	2
7	3	3	2	1	3	1	1	2	1	2	3	2
8	3	3	2	3	1	1	1	2	2	1	3	2
9	3	3	3	1	1	1	2	2	2	2	2(213 C)	2
10	2	2	3	2	2	2	2	1	2	1	2	1
11	3	1	2	1	1	2	1	1	2	1	2	3
12	2	2	2	2	3	1	1	1	2	1	2	2
13	2	1	2	3	3	1	1	1	1	1	1	2
14	2	3	3	3	2	1	2	1	1	1	2	2
15	2	1	3	1	2	1	1	1	1	1	2	2
16	2	1	2	2	2	1	2	2	2	1	1	2
17	2	3	1	2	1	1	2	2	2	1	2	2
18	2	2	2	1	2	1	1	2	2	1	2	2
19	2	1	1	2	2	2	1	2	2	1	1	2
20	1	3	2	1	2	1	2	3	2	1	1	2
21	3	2	2	3	2	1	2	2	2	1	1	2
22	2	2	2	1	2	1	1	1	2	1	1	2
23	2	4	2	2	2	1	1	1	2	1	1	3
24	2	2	2	2	2	2	2	1	2(211 D)	1	2	2
25	2	3	1	2	2	2	1	1	3	1	1	2
26	2	3	2	2	2	2	1	2	2	1	1	3
27	3	2	1	2	2	3	2	3	1	1	1	2
28	3	2	1	2	2	2	2	4	1	1	1	2
29	3		3	2	2	2	2	4(210 C)	2	1	1	2
30	2		1	2	2	2	2	3	1	2	1	2
31	2		2		2		2	2		2		2

Year 1955

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
1	3	3	3	2	2	3	2	2	2	2	2	2
2	2	3	2	2	2	2	3	2	3	3	2	2
3	3	3	2	2	2	2	2	2	3	3	2	3
4	2	2	2	2	3	3	2	2	2	3	2	3
5	2	2	3	2	2	2	2	2	2	3	2	2
6	2	2	2	3	3	2	2	2	2	3	2	2
7	3	2	2	3	2	2	4	2	2	3	2	2
8	2	3	2	3	2	2	3	2	2	3	2	2
9	3	2	3	2	2	2	2	2	3	3	3	2
10	4	4	3	2	2	2	1	2	2	3	3	2
11	3	3	2	2	2	2	2	2	2	3	2	2
12	3	2	3	2	3	3	4	2	2	2	2	2
13	3	3	2	2	2	2	4	2	2	2	2	2
14	4	3	3	2	2	3	3	2	1	2	2	2
15	4	3	3	2	3	3	2	1	2	2	2	4
16	3	2	2	2	2	2	3	3	2	2	3	3
17	3	2	4	2	1	2	2	3	2	2	3	2
18	4	3	3	3	2	2	2	1	2	3	2	2
19	4	3	2	2	2	2	3	2	2	2	2	2
20	4	4	2	2	2	2	3	2	2	2	3	2
21	2	2	2	2	2	2	3	2	2	3	2	2
22	2	2	2	2	2	2	3	3	2	3	2	2
23	2	2	3	2	1	3	3	4	2	3	2	2
24	2	2	2	2	2	2	2	5(214 B)	2	3	2	2
25	2	2	2	3	3	3	2	4	4	3	2	2
26	4	2	2	2	3	3	2	4	3	2	3	2
27	3	3	2	2	3	2	2	4	2	2	2	3
28	3	2	2	2	2	1	2	3	2	3	2	2
29	4		2	2	2	1	2	3	2	3	3	2
30	3		2	3	2	2	3	3	3	2	3	2
31	3		2		2		2	3		2		2

Year 1956

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept	Oct.	Nov.	Dec.
1	2	2	2	3	2	2	3	3($^{216}_{A}$)	3	2	2	2
2	2	1	2	2	1	2	2	5	4	2	3	2
3	3	1	2	2	2	3	2	3	5($^{217}_{D}$)	2	3	3
4	2	3	2	1	2	3	2	2	5	2	2	2
5	2	2	3	1	2	3	2	2	3	2	3	2
6	2	2	2	1	2	3	2	2	2	2	2	2
7	3	2	2	2	2	2	2	2	2	2	3	3
8	3	3	2	2	2	2	2	2	4	2	3	3
9	3	2	2	2	2	2	3	2	2	2	3	3
10	3	2	2	3	3	2	2	2	2	2	3	2
11	3	2	2	2	3	2	2	2	2	3	3	3
12	3	2	2	2	2	3	2	2	2	2	3	2
13	2	2	2	2	2	3	2	2	2	2	3	2
14	2	2	1	2	2	3	2	2	2	2	3	3
15	2	3	3	2	2	2	3	3	3	2	3	2
16	2	3	1	2	2	2	3	2	4	2	4	2
17	2	2	1	1	2	2	2	3	5($^{218}_{A}$)	2	4	2
18	3	2	1	2	2	3	2	2	4	3	3	2
19	1	2	1	3	2	2	2	2	4	3	2	2
20	2	3	2	3	2	2	2	2	3	3	3	2
21	2	2	1	3	2	2	2	2	4	3	3	2
22	2	2	1	3	2	2	2	2	5	2	3	2
23	3	2	1	3($^{215}_{C}$)	2	2	2	2	6($^{219}_{C}$)	2	3	3
24	2	2	2	2	2	2	2	2	4	2	3	3
25	2	2	2	2	2	2	2	2	2	2	3	3
26	2	2	1	2	2	2	2	3	2	2	3	2
27	2	3	2	2	2	2	2	2	3	2	2	2
28	3	2	2	2	2	3	3	3	2	2	2	2
29	2	2	1	2	2	3	3	2	2	2	2	2
30	1		1	2	2	3	4	2	2	2	2	3
31	2		2		1		4	3		2		2

Year 1957

Day	Jan.	Feb	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	3	2	3	3	2	2	1	3	1	2	1	2
2	2	2	3	3	1	2	1	4	1	3	1	2
3	2	3	2	2	1	2	3	2	2	2	1	2
4	2	2	2	2	1	1	4	2	2	1	1	2
5	3	3	3	2	1	3	3	2	1	2	1	2
6	2	2	3	2	1	2	2	1	1	2	2	2
7	2	2	2	2	2	1	1	1	1	2	2	2
8	3	2	4	1	1	1	1	1	1	1	2	2
9	2	2	2	2	1	1	2	1	2	1	1	1
10	2	3	2	3	2	1	3	1	3	1	2	1
11	2	4	3	2	2	3	1	1	3	1	3	1
12	3	4	2	2	2	1	1	0	2	1	3	1
13	3	3	3	2	1	1	2	3	2	1	2	2
14	3	3	3	2	2	2	3	3	4($^{221}_{C}$)	1	2	3
15	2	3	3	2	3	3	2	2	3	3	3	2
16	3	3	2	3	1	2	4	2	2	2	2	2
17	3	3	3	2	1	2	3	3	1	2	1	3
18	2	3	2	2	3	1	2	4	1	1	2	2
19	2	2	2	2	2	1	1	4	1	1	2	2
20	2	2	3	2	1	2	1	4	1	1	2	3
21	3	2	3	2	1	1	1	3	2	1	2	2
22	3	3	3	2	3	1	1	2	3	1	2	2
23	2	3	3	2	3	2	1	1	3	1	1	2
24	2	2	3	2	2	3	1	1	3	1	1	1
25	3	3	2	2	1	4($^{220}_{D}$)	2	1	3	1	1	1
26	3	3	2	1	1	2	2	2	3	2	1	2
27	2	3	2	1	1	1	1	1	1	2	1	2
28	2	3	3	2	1	2	2	1	1	2	1	3
29	3		2	2	4	2	1	1	0	3	2	3
30	2		2	2	4	1	1	1	0	3	2	3
31	3		2		2		2	1		2		2

Year 1958

Day	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec
1	3	3	2	1	1	2	1	1	2	2	3	1
2	3	3	3	2	2	2	1	1	2	2	3	2
3	3	2	2	1	1	3	1	2	2	2	2	2
4	1	2	2	1	2	3	1	3	2	2	1	2
5	1	3	1	2	2	3	1	2	3	2	2	1
6	1	2	1	1	2	2	1	1	1	3	2	2
7	1	3	3	1	1	1	1	2	1	3	2	2
8	1	2	2	1	1	1	1	1	1	2	2	2
9	1	3	1	1	2	2	1	1	2	2	2	2
10	1	3	1	1	1	1	1	1	3	1	2	1
11	1	2	1	2	1	1	2	1	2	1	3	1
12	1	2	1	3	3	1	2	1	3	1	2	1
13	1	1	1	2	1	1	1	1	1	2	2	2
14	2	1	1	1	1	1	2	1	1	2	2	1
15	3	2	1	1	1	1	3	2	1	2	2	1
16	3	2	1	1	2	2	5($^{222}_{B}$)	1	1	1	3	1
17	3	1	2	1	2	1	4	1	1	1	2	1
18	2	3	1	1	1	2	2	1	1	2	2	2
19	3	3	1	1	1	1	2	1	1	3	2	2
20	2	2	2	3	1	1	3	1	1	3	3	3
21	3	3	3	1	2	1	2	1	1	2	2	2
22	3	2	1	1	1	2	3	1	1	3	3	2
23	2	1	1	1	2	1	4	1	1	1	3	1
24	1	1	1	1	1	1	3	1	1	2	2	1
25	1	1	1	1	1	1	3	2	1	3	2	2
26	1	0	3	1	1	1	2	1	1	2	1	3
27	1	3	3	3	1	1	2	1	2	2	2	2
28	2	2	2	2	1	1	2	1	2	2	2	2
29	1		2	2	1	1	1	2	2	3	3	3
30	2		1	2	2	2	1	3	1	3	3	3
31	2		1		3	1	1	4($^{223}_{A}$)		3		2

Year 1959

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	2	1	3	2	2	2	1	2	4	1	1	1
2	3	1	3	1	1	2	1	1	3	1	1	2
3	3	2	1	2	2	2	2	1	2	2	2	2
4	3	2	1	2	2	2	2	2	3	1	1	1
5	2	2	2	2	2	2	2	3	2	1	1	2
6	2	2	3	1	1	2	4	3	2	2	1	2
7	2	3	3	1	1	2	3	4($^{226}_{F}$)	2	1	2	1
8	2	3	3	1	1	2	3	4	2	2($^{230}_{F}$)	1	2
9	3	3	2	2	2	1	2	3	2	3	1	2
10	3	2	2	2	1	1	3	2	3	2	1	2
11	2	2	2	3	1	2	2	1	3	1	1	2
12	3	2	2	1	2	2	2	2	1	1	3	2
13	3	3	2	1	2	1	1	2	1	1	1	1
14	2	1	2	1	1	1	1	2	1	1	1	2
15	2	1	3	1	2	2	3($^{225}_{A}$)	2	3	1	1	2
16	3	3	3	2	1	1	3	2	2	1	2	2
17	2	2	2	2	1	1	3	2	2	1	1	2
18	2	1	2	1	2	1	2	1	2	2	3	2
19	1	3	2	1	2	1	2	2	2	2	3	2
20	2	2	2	1	1	1	2	2	1	1	2	1
21	3	2	1	1	1	1	2	3	2	1	1	2
22	3	2	2	1	2	1	1	2	2	2	2	2
23	2	1	2	1	2	1	1	3($^{227}_{C}$)	3	1	2	2
24	2	1	2	2	2	1	1	2	1	2	2	2
25	1	2	2	1	2	1	1	1	1	1	2	2
26	2	2	1	1	1	1	1	2	1	1	2	2
27	1	3	2	1	1	1	1	2	1	2	1	2
28	1	3	2	1	1	1	1	2	1	1	2	2
29	1		3	1	1	1	2	2	1	1	1	2
30	2		2	1	2	1	2	3	1	2	2	2
31	3		2		2		2	3		1		2

Year 1 9 6 0

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.
1	2	2	1	1	1	1	3	$3\binom{234}{A}$	1	1	1	1
2	1	3	1	1	1	1	2	3	1	1	1	1
3	1	2	1	1	1	1	1	2	1	1	1	1
4	1	2	2	2	1	1	1	2	1	1	2	1
5	2	1	2	1	1	3	1	2	1	1	1	1
6	2	2	2	2	1	4	1	1	1	1	1	1
7	2	1	3	1	1	5	1	1	1	1	1	1
8	2	2	2	1	1	5	1	$3\binom{235}{A}$	1	1	1	1
9	2	1	3	1	1	5	1	2	1	1	1	1
10	2	2	2	2	1	$5\binom{233}{G}$	1	1	1	1	1	1
11	2	1	2	2	1	4	1	1	1	1	1	2
12	1	1	3	1	1	4	1	1	1	1	2	1
13	2	3	1	1	1	3	1	1	1	2	1	1
14	1	1	2	2	1	3	1	$2\binom{236}{A}$	1	2	1	1
15	3	1	3	3	1	3	1	2	1	2	1	1
16	1	1	3	3	1	3	1	1	1	2	1	1
17	1	3	3	3	1	2	1	1	1	2	1	2
18	1	1	2	2	1	1	1	2	1	1	1	1
19	1	2	2	2	1	1	2	2	1	1	1	1
20	2	2	2	2	1	1	1	2	1	1	1	1
21	2	2	1	1	1	1	1	3	1	1	1	2
22	2	2	1	1	2	1	1	4	1	1	1	1
23	2	1	1	1	2	1	1	5	1	1	1	2
24	2	1	1	3	2	3	2	$5\binom{237}{F}$	1	1	1	2
25	2	2	1	$3\binom{232}{F}$	2	2	1	3	1	1	1	1
26	2	1	1	2	1	1	1	3	1	1	1	1
27	2	2	1	2	1	2	1	2	1	1	1	1
28	2	2	1	1	1	3	1	2	1	1	1	2
29	1	2	1	1	1	4	1	2	1	1	2	2
30	2		1	1	1	4	1	1	1	1	1	2
31	2		1		1		2	1		1		1

Year 1 9 6 1

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	1	3	1	1	1	1	2	1				
2	1	2	1	1	1	1	2	1				
3	2	1	1	1	1	1	2	1				
4	1	2	1	2	3	1	1	1				
5	1	3	1	1	1	1	1	1				
6	1	1	1	1	1	1	1	1				
7	1	1	1	1	1	2	1	$3\binom{240}{B}$				
8	1	1	1	1	1	2	1	3				
9	2	1	1	1	1	1	1	2				
10	1	1	1	1	1	1	1	1				
11	1	1	2	1	1	1	1	1				
12	2	1	1	1	1	1	1	1				
13	2	3	1	2	1	1	1	1				
14	2	2	1	2	2	1	$3\binom{239}{C}$	1				
15	1	2	1	1	1	1	3	1				
16	3	2	1	1	1	1	2	1				
17	2	1	1	1	1	1	1	1				
18	1	1	1	1	2	1	1	1				
19	1	1	1	1	3	1	2	$1\binom{241}{C}$				
20	2	2	1	2	2	1	1	1				
21	1	1	1	2	1	1	1	1				
22	1	1	1	1	1	1	1	1				
23	3	1	2	1	1	2	1	1				
24	1	1	3	1	1	3	1	1				
25	1	1	2	1	1	1	1	3				
26	1	1	2	1	1	1	1	3				
27	1	1	1	1	$1\binom{238}{F}$	1	1	3				
28	1	1	1	1	1	1	1	2				
29	2		1	1	3	1	1	1				
30	2		1	1	1	2	1	1				
31	3		1		1		1	1				

Year 1 9 6 2

Day	Jan.	Feb.	Mar.	Apr.	May	June
1	2	1	2			
2	1	1	1			
3	1	2	1			
4	1	1	1			
5	1	1	1			
6	1	1	1			
7	2	1	1			
8	2	1	1			
9	2	1	1			
10	2	2	1			
11	1	2	1			
12	2	1	1			
13	2	1	1			
14	1	1	1			
15	1	1	1			
16	2	1	1			
17	1	1	1			
18	1	1	1			
19	2	1	1			
20	1	1	1			
21	1	1	2			
22	1	1	1			
23	1	1	1			
24	1	1	1			
25	1	1	1			
26	1	1	2			
27	2	1	1			
28	2	1	1			
29	1		2			
30	1		1			
31	1					

Table-4.10 Monthly Frequency of Wave Degree during 10 Years

(Nine years' record is converted into ten years' for Sept. to Dec.)

Wave degree	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
0		1						1	2				4
1	98	84	116	123	137	122	122	100	102	128	102	74	1,308
2	138	122	132	141	142	113	116	130	139	135	145	190	1,643
3	65	70	58	36	27	49	46	54	36	44	58	46	589
4	9	5	2		4	9	16	17	13	2	5	1	83
5						3	6	6	3				18
6							1		2				3
7							1						1

Table-4.11 Remarkable Waves at Kaohsiung

Date	Wave degree	Typhoon No. & course	Wind at Kaohsiung	
1952. 6 13	3			
14	4			
15	3	① D	SE ~ SW <10 m/s	
6.20	3		WNW < 5	
21	5	② E	NW ~ WNW < 10	
22	2		W ~ WNW < 15	
6 28	4			
29	4			
7. 6	4			
7	4			
8	4			
7 17	5		午后 WSW < 20	
18	7	⑤ C	W ~ SW < 15	
19	4		SSW < 10	
7.29	5	⑥ B	SE < 25	
30	4		SE < 20	
9 1	4	⑪ D	NNE < 10	
2	3		S < 15	
9.11	4		W < 5	
12	5		SSE < 15	
10 11	4	㉑ D	< 5	
10 31	4		< 5	
11.13	4		SE < 10	
14	3	㉑ D	SE < 15	
11.26	3		W < 5	
27	4	㉓ D	SE < 20	
12 4	4		NNE < 10	
1953 1.31	4		NNE < 10	
5.27	4		WSW < 10	
28	4		WNW < 10	
6. 6	5	② E	NW < 10	
7	5			
6.30	4	③B	SSE < 10	
7 3	5		NNE < 10	
4	6	④ C	NNW ~ SW < 15	
5	5		SE < 15	
8 16	5	⑦ C	W ~ NW < 15	
17	5		WSW < 15	
18	5		ENE < 10	
19	5		W < 5	
20	4		WNW < 5	
21	4	⑨ C	SSE < 15	
9 1	6	⑩ B	NE ~ SE < 30	
2	4		SE < 20	
10. 3	3	⑯ E	ESE < 10	
11 18	4		ENE < 15	
1954 7. 2	4		SSE < 10	
8.28	4			
29	4	⑧ A	SE < 10	
9.24	2	⑮ E	E ~ NW < 5	
11 5	2	⑲ A	NNW ~ NE < 5	
11.11	2	㉕ A		
1955 1.10	4		NNE < 5	
1.14	4		NE ~ NNW < 5	
15	4		〃 < 5	
1 18	4		NNW < 5	
19	4		〃 < 5	
20	4		NE ~ NNW < 10	
1.26	4		NE ~ NNW < 10	
1 29	4		NNE ~ NNW10	
2 10	4		NNW < 10	
2.20	4		NNE < 20	
3 17	4		SSE < 10	
7. 7	4			
12	4	⑧ E	NNW < 5	
13	4		〃 < 5	
8 23	4	⑲C	NNW < 5	
24	5		NNW ~ SW < 15	
25	4			
9 25	4	㉑ A	NW < 5	
1956 4.23	3	③ E	N < 10	
7.30	4		NNW < 5	
31	4		〃 < 15	
8 1	3	⑥ C	〃 < 10	
2	5			
9 2	4		NE ~ NNW < 10	
3	5	⑪C	NNW < 25	
4	5		S < 10	
9 8	4		NNW < 15	
9 16	4		WNW ~ NNW < 10	
17	5	⑬C	SSW < 20	
18	4		SE < 15	
19	4			
9 21	4			
22	5	⑭ C	NNW < 10	
23	6		SE < 25	
24	4			
11.16	4		< 5	
17	4		NNW < 10	
1957. 2.11	4		NNW < 5	
12	4			
5.29	4		SSW < 10	
30	4		ESE < 10	

Date	Wave degree	Typhoon No. & course	Wind at Kaohsiung	
6 25	4	⑤ C	NNW ~ W <15	
7 16	4	⑥ A	ESE <15	
1957. 8.18 19 20	4 4 4		NNE < 5 NW < 5 E < 5	
9.14	4	⑪ B	E ~ ESE <20	
1958. 7.15 16 17	3 5 4	C	< 5 W <20 E <10	
8 30 31	3 4	C	SE <10 ESE <10	
1959 3 15 16	3 3	C		
7 6	4	A	ESE <10	
7.15	3	C	NW <10	
8. 7 8	4 4	NE across Taiwan	WSW <20 〃 <15	
8 23	3	B	夜 E ~ SSE <10	
9 1	4	C	SE <10	
10. 9	3	E		
1960 4 25	3	E	< 5	
6 6 7 8 9 10 11 12	4 5 5 5 5 4 4	E	< 5 SE <10 ESE <10 E ~ ESE <10 SSE ~ SW <10 WSW <10 0	
6 29 30	4 4	A	ESE <10 SE <10	
8 1	3	C	WSW <15	
8 8	3	C	NNW <10	
8 14	2	C	NNW < 5	
8 22 23 24	4 5 5	E ~ C	NW <10 W ~ NW <15 SW <15	
1961 5 29	3	D	ESE <15	
6 8	2	C	SE <10	
6 27	1	C	< 5	
7. 1	2	B	ESE <10	
7.14	3	C	ESE <10	
7 19	2	A	ESE <10	
8 25	3	C	NNW ~ SW <15	

4. Tide and Tidal Current

4.1 Tide

(1) Table-4.12 shows the tide constants along Taiwan coast. The diurnal inequality is remarkable around Keelung and along the southwestern coast. Tidal range is big along the northwestern and western coast. Mean water level is highest in August while lowest in January, the difference being 0.2～0.3m.

(2) Kaohsiung Harbour has two tide observatories: one belongs to the Harbour Bureau (beside the 3,000 ton repairing dock) and the other to the weather observatory (just inside the harbour entrance). The old observatory at Chiching outside the harbour is scheduled to be repaired and used again in future. The predicted astronomical tide level is contained, together with that of Keelung, in Tide Table Vol.2 issued by Hydrographic Department, Maritime Safety Agency, Japan.

(3) Table-4.13 is the daily tide record in 1964 by the Harbour Bureau tide-gauge. High high-water is generally followed by low low-water, and their interval is 7 ～ 9 hours.

(4) Secondary oscillations are not obvious so far as the tide record studied in 1964 is concerned. Water level elevation of 10 20 cm due to typhoon was found in the records of 22 July, 6 Aug., 5 Sept. in 1962 and of 16 July, 10 Sept. in 1963.

(5) The cross-sectional area of the existing harbour entrance is fairly small compared with the water surface area of the inner harbour, but does not seem so small as to cause a considerable difference of tidal range between the inner harbour and the outer sea.

4.2 Tidal current

(1) The current speed is less than 0.5 knots outside the breakwaters.

(2) According to the observation by means of a float on 9 July 1964, the surface flood and ebb current speeds through the entrance channel were 68 cm/sec (19h30m) and 73 cm/sec (10h45m) respectively.

Note) It was 1 June by the lunar calendar and the tide was 135cm at 7h, 24cm at 15h and 63cm at 21h.

(3) According to the observations with an Ekman-Mertz current meter around the mooring buoys in the harbour during 28 Aug. ～ 6 Oct. 1963 , both the flood current towards inside and the ebb current towards the commercial wharves or the entrance channel were 0.2 ～ 0.3 m/se .

(4) The biggest problem concerning the tidal current is to ascertain to what extent it contributes to maintaining the water depth in the existing entrance channel, where the bottom consists of coral reef covered with a thin layer of sand and mud, as the maintenance dredging has never been executed, and the trough just inside the entrance always keeps its water depth reaching -16m. The tidal current velocity through the entrance will naturally decrease following the opening of the second entrance together with the reclamation in the inner harbour. Its effect on the siltation and water pollution should be taken into consideration.

(5) Table-4.14 shows the roughly estimated current velocity through the entrances in future.

Table-4.12 Tide Constant in Taiwan

	M_2	S_2	K_1	O_1
Taitung	cm 43	18	16	16
Keelung	19	5	19	15
Tanshui	100	31	20	17
Houlung	163	50	20	17
Makung	87	23	25	21
Kaohsiung	15	6	16	15

Note) The upper rank of Sp.R is for the equinoxial tide and the lower one in ( ) is mean high high water of the tropic tide.

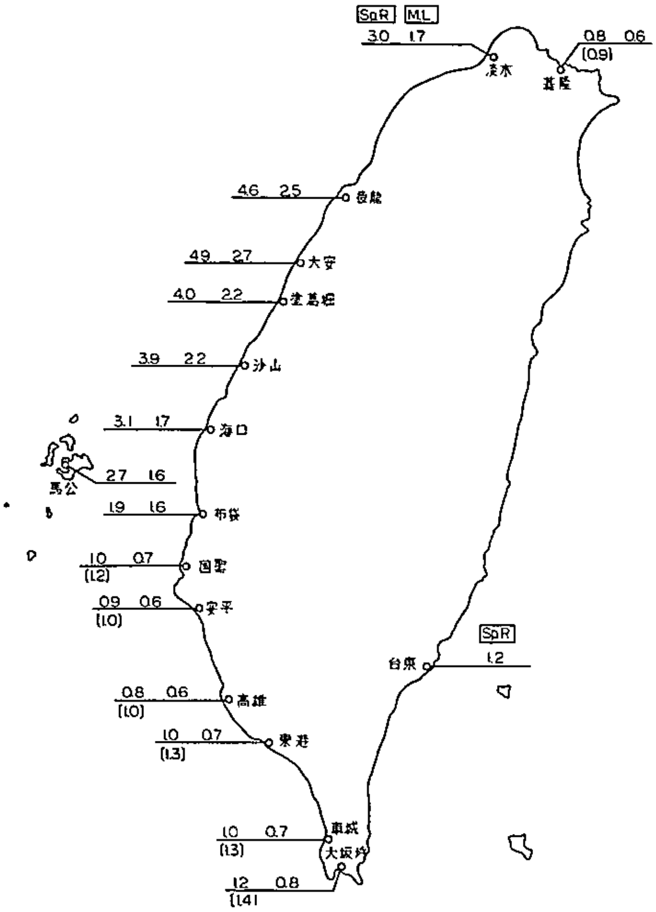


Fig. 4-4 Tide Constant

Table-4.13 Monthly Tide Record at Kaohsiung

(Kaohsiung Harbour Bureau Tide Gauge, 1964)

unit : cm

datum level : 60cm below mean sea level

Month	Highest high water	Lowest high water	Highest low water	Lowest low water	Max. range	Mean level
Jan.	110	47	55	8	88	57
Feb.	102	46	49	2	83	50
Mar.	106	36	61	6	77	54
Apr.	126	58	74	19	106	67
May	134	49	70	18	115	68
June	145	50	66	24	101	68
July	153	65	72	30	115	75
Aug.	128	67	62	27	93	77
Sept.	119	68	71	28	86	70
Oct.	121	52	71	17	101	66
Nov.	125	38	64	3	121	59
Dec.	123	38	60	13	105	57

Note) According to the lunar calendar 1st January falls on 13 February, 1964.

Table-4.14 Estimated Current Speed through the Entrance Channel

A	S	2a	U_{max}	Remarks
14 km^2	1200 m^2	110 cm	90 cm/s	before reclamation
		80	65	
		50	41	
12	1200	110	64	Present status
		80	47	
		50	29	
9	1200	110	58	after reclamation
		80	42	
		50	26	
9	3700	110	19	after the opening of the second entrance
		80	14	
		50	9	

$$U_{max} = \frac{2\pi}{T} \cdot \frac{A}{S} \cdot a$$

where, a = semi-tidal range

A = water surface area of the inner harbour

S = cross-sectional area of the entrances

T = period of tide (12.5 hr)

5. Littoral Drift

5.1 Littoral drift around the existing harbour entrance

(1) According to the marine chart No.219 (Kaohsiung Harbour) issued by Hydrographic Department, Maritime Safety Agency, Japan, the variation of water depth is very small between its old edition (1938) and the new one (1956). Only such changes are cognizable as the advance of -10m contour line around the south breakwater head and the appearance of -5m bar outside the same breakwater. Contour lines of -10m and -5m in other parts, and, especially -10m bar off the south breakwater head show a surprising concidence in both editions. The shorelines along both the north and south beaches seem to have slightly receded.

(2) Periodical sounding maps made by the Harbour Bureau (the maps consisting of 14 leaves and covering the period from June 1954 to Oct. 1964) indicate a tendency of the advance of the bar around the south breakwater head, as shown in the marine charts, and the siltation as far as the middle of the outer harbour fairway. The rest of the outer harbour shows little change in the water depth except that due to dredging, and seems to be scarcely affected by the disturbance of invading waves.

(3) Table-4.15 is the amount of the dredged material since 1955. The total amount of maintenance dredging in the outer harbour fairway has com up to about 180,000 cubic metres, that is, less than 50,000 cubic metres per year on the average.

(4) The dredged material of nearly 1,900,000 cubic metres from the inner harbour has been brought into the outer sea about 2.5km to the south of the south breakwater foot during 1961 1964. This is considered to have had a certain effect on the recent rapid advance of the bar around the south breakwater head.

(5) A more definite tendency may be obtained by comparing the water depth variation in each part during each period with the amount of the dredged material and meteorological conditions during the same period, and also by analyzing the bottom materials around the outer harbour.

5.2 Littoral drift in the neighbouring coast

From the beach inspection of the survey mission (Anping~Tungchiang), the opinion expressed in Reference-4.1 and other informations, the following are considered to be the general tendency of the littoral drift along the neighbouring coast.

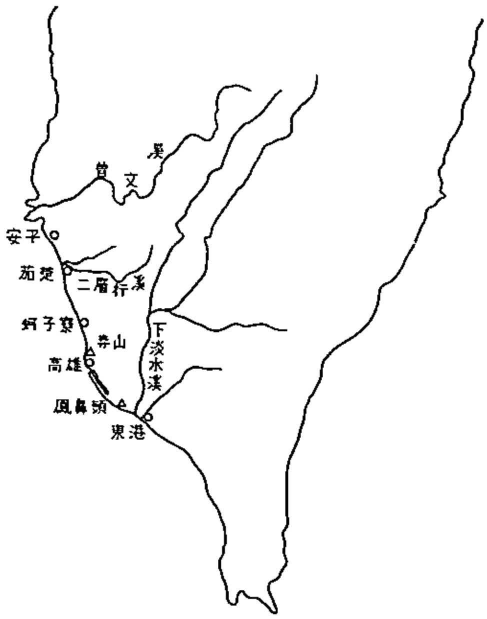


Fig. 4-5 Neighbouring Coast of Kaohsiung

(1) Along the coast south of the mouth of the Tsengwen-chi, the northward sand drift exceeds the southward one.

(2) A fairly big amount of sediment is discharged in the rainly season from the Tsengwen-chi, Erhjen-chi and Kaoping-chi, but the influence is rather limited around the river mouths.

(3) Near such river mcuths, the littoral drift moves northward in summer causing erosion, and southward in winter causing sedimentation.

(4) Such seasonal variation is bigger than the annual change with a constant tendency. The yearly difference is governed by the characteristics of typhoon and flood in each year.

(5) Even if the above-mentioned rivers are the ultimate source of the sand drift near Kaohsiung coast, their direct influence will be small.

(6) Namely, north of Kaohsiung Harbour, the influence of the Erhjen-chi is limited up to Hsiachieting. Kotzuliao shows a tendency of erosion. Shoushan cuts off the southward sand transport.

(7) In the south, the sediment from Kaoping-chi is not considered to reach even Fengming. The existence of a spit at Fengming and an eroded beach at Hungmaochiang seem to show that there is hardly a big amount of supply from the Kaoping-chi to Kaohsiung coast.

(8) The direct sources of sand drift around Kaohsiung harbour are the northern narrow beach and the southern beach, where neither annual nor seasonal change is so remarkable.

5.3 Littoral drift near the second entrance

(1) As mentioned above, the amount of littoral drift near the second entrance is not likely to come out so large. It will be enough to perform a certain amount of maintenance dredging and some shore protection works, if necessary.

(2) However, in order to get a more definite concept of the potential beach process, it is indispensable to observe carefully the sedimentation or erosion attendant upon the progress of the second entrance construction worksbby executing periodical sounding and other investigation programmes.

Table-4.15 Amount of Dredged Material at Kaohsiung Harbour

1. Dredging for maintenance and development

1955,	9 May ~ 31 July	146,122 cu.m.	inner & outer harbour
1956,	6 Nov. ~ 31 Dec.	115,453	" "
1957,	1 Jan. ~ 7 Sept.	557,628	" "
1959,	6 Apr. ~ 30 May	97,078	outer harbour
	"	7,390	inner harbour
1960,	26 May ~ 20 Sept.	65,458	outer harbour
1960,	19 Dec. ~ 20 Dec.	2,980	

2. Dredging entrusted by Navy (northern part of the navigation channel in the outer harbour)

1959,	2 Nov. ~ 31 Dec.	68,218 cu.m.
1960,	1 Jan. ~ 22 July	284,750
	1 May ~ 23 July	45,175
	unknown	261,700
1961,	6 Apr. ~ 31 Oct.	29,156

3. Dredging for maintenance and development

Year	Outside the breakwaters	Inside the breakwaters	Inner harbour
1961	26,200(-11.5)	49,235(-11.0)	28,500
1962			272,198
1963	96,881(-11.5)	11,790(-11.0)	153,249
1964			328,390
1965	220,000(-12.0)	100,000(-11.5)	441,026

4. Discharged amount to outer sea out of extension works' debris

(at 2.5 km from the south breakwater foot)

		(From 7th navy dock)	
1962	414,280 cu.m.	245,416 cu.m.	
1963	413,270	426,960	
1964	410,390		
total	1,237,940	672,376	1,910,316

Reference-4.1 Littoral Drift along the West Coast of Taiwan
(summarized from T. Ijima, "Report on the Inspection of the West Coast of Taiwan", 1962)

By examining the coast from Hsinchu to Hengchun via Chiting, Houlung, Tunghsiao, Wuchi, Yunlin, Tunghsih, Putai, Kaohsiung and Fangliao, it is understood that the most beaches have been formed of the sediment from a lot of rivers and are composed of fine sand of smaller than 0.1 0.2mm.

The beaches were fortunately able to develop owing to the abundance of sediment supply. At present, however, rivers are being improved and the sediment transport is gradually getting reduced. Therefore, beach erosion can now be seen everywhere on the west coast, in other words, an erosion age has already started.

The following are the author's opinion based on his inspection of the beaches.

(1) It can be said that the beach near Chiali has been formed of the sediment from the Tsengwen-chi and that Waisantingchou and Haifeng Island have been formed of that from the Choshui-chi. The author thinks that Waisantingchou was formed first, Haifeng Island next and finally Chiali beach, but this should be studied more by old data.

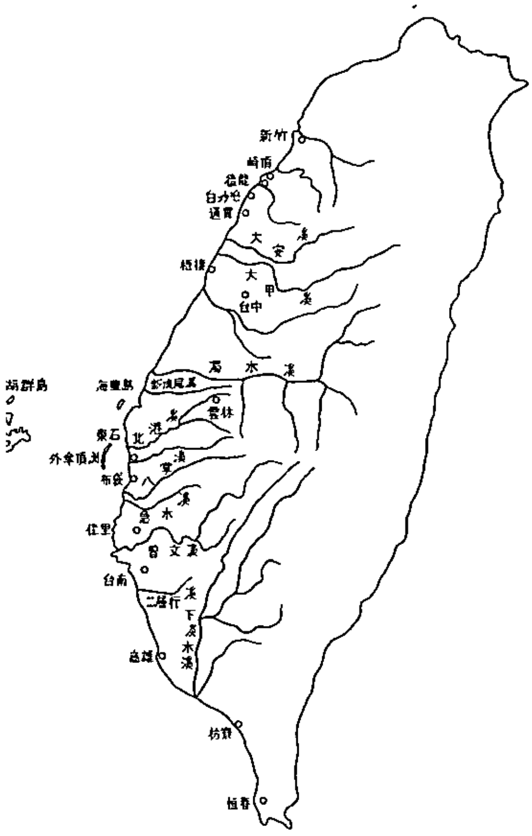


Fig. 4-6 Western Coast of Taiwan

(2) The formation of Waisantingchou has affected the beaches situated to its south. Because, north of Waisantingchou, the waves generated by the NNE monsoon in winter has much greater influence on the littoral drift than the waves from southwest in summer, whereas the southward sand drift terminates at Waisantingchou and gives no supply to the southern beaches.

Haifeng Island showed up owing to the southward littoral drift after it had been cut off by the formation of Waisantingchou. The formation of Haifeng Island itself also checked the sediment supply to Waisantingchou and seemed to have caused the erosion of the latter. The appearance of Haifeng Island is related to the northward movement of the sediment from the Choshui-chi and of the river mouth itself.

(3) The axes of Haifeng Island and of Waisantingchou are parallel to each other and have the same direction as the low water shoreline of the coast lying to their north. Although these two bars were formed at different periods, it seems that both of them were created by the sediment from the Choshui-chi, blown sand and alongshore drift sand.

(4) Afterwards, part of Haifeng Island began to be eroded because of the decrease of the sediment from the Hsin Huwei-chi, and its tip gradually diminished, while extending southward, and finally disappeared.

Waisantingchou also reduced its whole size due to the decrease of supply caused by the formation of Haifeng Island. The low water shoreline along its outer face receded by 1km on the annual average during 30 years. Its tip also gradually diminished while extending to the south, which clearly shows the tendency of the southward littoral drift.

(5) As the southward sediment had been cut off in the part south of Waisantingchou, the beaches between Tungshih and Putai were supplied only by the northward sand drift as seen in front of Putai, where all the bars extend from south to north.

The source of supply may have been the Tsengwen-chi in the past, but is now the Peichiang-chi, Pachang-chi or Chishui-chi. The amount is very little and may be decreasing.

Bars and beaches in this district seem to be under erosion. A new bar was formed just north of the mouth of the Pachang-chi and extended to the north, which indicated the northward sand drift. Therefore, it is required to investigate the distribution of the discharged sediment from the Pachang-chi and Chishui-chi.

(6) The sheltering effect of Waisantingchou from the northern waves decreases, and, therefore, the southward sand drift in winter increases in proportion to the distance from Waisantingchou. The northward drift in summer also increases in the south. It is required to estimate the amount of the sand drift in both directions at each place, by calculating from the wind data, the wave energy transport along the coast throughout the year.

(7) According to old maps, the bars in front of Tsenpa sand beach seem to have been formed by the gradual southward movement of the channel of the Tsenwen-chi and have extended southward. However, from the fact that all the bars are situated to the north of the mouth of Tsengwen-chi, it is also probable that they have been formed of the northward sand drift. It is necessary to investigate the maps of old edition.

(8) Connecting Anping or Kaohsiung by a straight line to Tungshih, which is sheltered by Waisantingchou, it is understood that the district west of the line forms a delta of the Tsengwen-chi, and the beaches in this district are mostly under its influence. The delta extends to the north with the mouth of the Tsengwen-chi as its summit. This phenomenon means that the sediment from the river has tended to deposit in the north.

This opinion is also demonstrated by the fact that the geographical change due to flood took place mostly in the northern side of the Chishui-chi and Tsengwen-chi. Namely, it is conceivable that the Tsengwen-chi moved southward while discharging the sediment northward.

North of Tungshih is under the influence of the Choshui-chi. However, contrary to the Tsengwen-chi, the Choshui-chi moved northward, depositing its sediment southwards.

The height of those bars which were formed of the sediment from the two rivers reach about

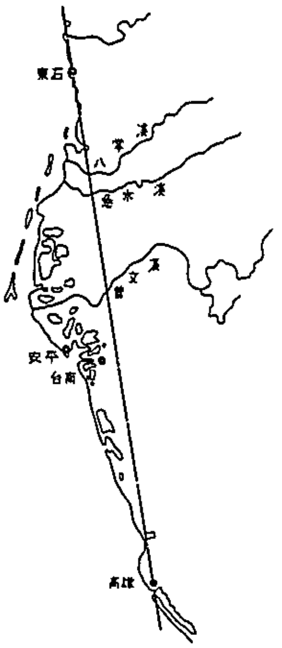


Fig. 4-7 Tsengwen-ehi Delta

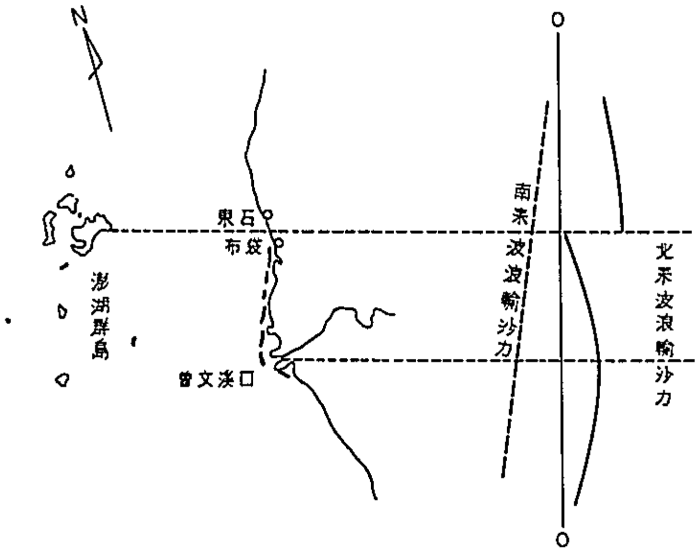


Fig. 4-8 Transport Capacity of Wave

From the above-mentioned facts, the west coast can be divided into two parts with Tungshih Putai as the boundary in view of the form and development of the beach. This boundary is just confronted with Peng Hu Islands and causes the change in waves and littoral currents.

North of this boundary, the transporting capacity of the waves from the north in winter is far bigger than that of the waves from the south in summer. The phenomenon is opposite south of the boundary. It is probable that the action of tide, tidal current and wind has a similar tendency.

6. Soil Condition and Earthquake

6.1 Soil condition

Reference-4.2 is the result of the soil test for three spots in the reclaimed area in the inner harbour.

6.2 Earthquake

(1) Earthquakes of big scales have been frequently recorded in most parts of Taiwan except Kaohsiung and the neighbouring district, where the occurrence of earthquake is very rare. Accordingly, it is not likely to cause such a disaster as that of Niigata-earthquake in Japan in spite of the similarity in their soil conditions.

(2) Reference-4.3 is the earthquake records in Taiwan (from Scientific Almanac, Tokyo Astronomical Observatory, Japan, and from a table presented by Mr. Hsu Ming-Tung, Taiwan Provincial Weather Bureau).

(3) Reference-4.4 is the general characteristics of earthquake in Taiwan, summarized from Mr. Hsu Ming-Tung's paper submitted to the 3rd World Conference on Earthquake Engineering held in New Zealand, 1965).

Reference-4.2 Soil Test for Kaohsiung Industrial Harbour

(tested by Civil Engineering Department, Cheng-Kung University)

Date : 12 Nov. ~ 8 Dec., 1964

Spot : 3

Depth : 30~40m

Standard penetration test : every 5 ft. or change of layer

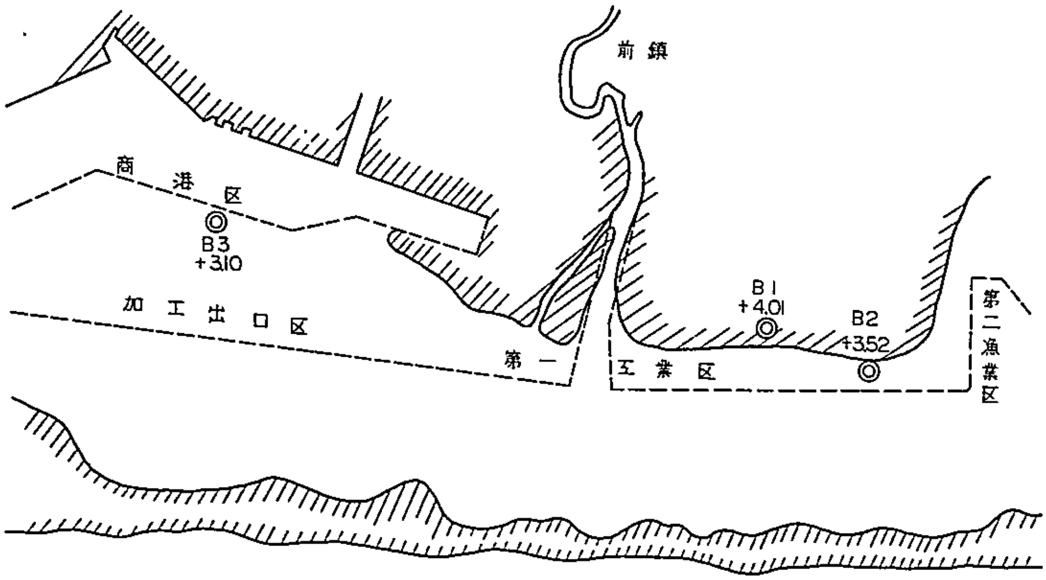


Fig. 4-9 Soil test spot

Sampler: 2in Split Spoon   G.W.L.: -1.4m from G.L.   Date: Nov. 12~16 '64 / Dec. 7~8 '64

Boring No. B1

Boring					Soil Tests									
Sample No.	Elevation (m)	Depth (m)	Log	N	Soil Classification	Natural Water Content (%)	Specific gravity	Dry Density gr/c.c.	Void Ratio	L.L. (%)	P.L. (%)	P.I. (%)	qu T/SF	qa T/SF
	+4.01	0 1.0			Gr. fine sand (SM)									
S1		2 2.75		4	Gr. fine sand with shell (SO)	26.5	2.66	1.65	0.61	—	Np	—	—	0.4
S2		3.8		1	Gr. clay (CL)	32.0	2.72	1.41	0.93	47.8	30.8	17.0	0.2	0.2
S3				2		20.6	2.68	1.64	0.63	—	Np	—	—	0.9
S4		6		3	Gr. sandy loam with shell (SM)	22.4	2.68	1.66	0.61	—	〃	—	—	1.4
S5		8 8.6		6		21.9	2.68	1.68	0.60	—	〃	—	—	1.8
S6		10		13		14.9	2.66	1.74	0.53	—	〃	—	—	3.4
S7				7	Gr. fine sand (SP)	23.5	2.66	1.64	0.62	—	〃	—	—	2.4
S8		12 12.3		5		21.3	2.66	1.67	0.59	—	〃	—	—	3.1
S9		14		17		21.9	2.68	1.77	0.51	—	〃	—	—	6.6
S10		16		18	Gr. sandy loam (SM)	24.5	2.68	1.71	0.57	—	〃	—	—	8.2
S11		17.1		25		21.2	2.68	1.81	0.48	—	〃	—	—	14.1
S12		18 18.5		20	Gr. fine sand (SM)	23.8	2.68	1.76	0.52	—	〃	—	—	11.2
S13		20		22		22.2	2.68	1.74	0.54	—	〃	—	—	13.3
S14		22		24		20.2	2.68	1.83	0.46	—	〃	—	—	16.6
S15				31		20.8	2.68	1.83	0.46	—	〃	—	—	30.0
S16		24		25	Gr. sandy loam (SM)	25.7	2.68	1.69	0.58	—	〃	—	—	20.3
S17		26		31		24.0	2.68	1.77	0.51	—	〃	—	—	33.8
S18		28		31		21.7	2.68	1.82	0.47	—	〃	—	—	35.8
S19				25		25.2	2.68	1.66	0.61	—	〃	—	—	24.0
S20		30 30.7		22		35.1	2.68	1.63	0.64	—	〃	—	—	20.2
S21		32 32.4		29	Gr. fine sand (SM)	27.0	2.68	1.62	0.65	—	〃	—	—	27.5
S22		34		67		21.4	2.69	1.81	0.49	—	〃	—	—	127.0
S23				39		23.8	2.69	1.84	0.46	—	〃	—	—	70.0
S24		36		37	Gr silty loam (ML)	18.7	2.69	1.91	0.41	—	〃	—	—	65.7
S25		38		35		24.6	2.69	1.77	0.52	—	〃	—	—	63.0
S26		40		29		30.6	2.69	1.57	0.70	—	〃	—	—	44.2

Remarks : qa shows allowable bearing capacity of soil on the basis of footing width 5 ft.

Sampler: 2in Split Spoon　　G.W.L. : -0.75m from G.L.　　Date : Nov. 17~19 '64, Dec. 4~5 64

Boring No. B2

Boring					Soil Tests									
Sample No.	Elevation (m)	Depth (m)	Log	N	Soil Classification	Natural water Content %	Specific gravity	Dry Density gr/c.c.	Void Ratio	L.L. %	P.L. %	P.I. %	qu T/SF	qa T/SF
	+3.52	0		▽										
S1		2 2.45		4½	Gr. fine sand (SM)	22.2	2.68	1.68	0.60	—	Np	—	—	0.4
S2		4.2		½	Gr. clay with shell (CL)	37.9	2.72	1.42	0.92	42.6	30.0	12.6	0.13	0.2
S3		5.7		4	Gr. sandy loam (SM)	29.7	2.68	1.63	0.64	—	Np	—	—	0.9
S4		7.35		1½	Gr. silty loam (ML)	28.5	2.69	1.54	0.85	23.2	12.8	5.4	—	1.1
S5		8		0	Gr. clay (CM)	48.8	2.73	1.23	1.22	64.3	37.2	27.1	0.13	0.2
S6		99.1 10 10.4		6½	Gr. sandy loam with shell (SM)	24.6	2.68	1.62	0.65	—	Np	—	—	2.1
S7				21	Gr. fine sand with shell (SW)	14.9	2.66	1.87	0.42	—	〃	—	—	7.1
S8		12 12.6		13		17.9	2.66	1.73	0.54	—	〃	—	—	4.5
S9		14 14.5		13	Gr. fine sand (SM)	18.0	2.68	1.68	0.60	—	〃	—	—	5.0
S10		16		15	Gr sandy loam (SM)	24.0	2.68	1.74	0.54	—	〃	—	—	6.4
S11				19		21.0	2.68	1.83	0.47	—	〃	—	—	9.5
S12		18		16		25.2	2.68	1.71	0.57	—	〃	—	—	8.2
S13		20		17		23.1	2.68	1.79	0.50	—	〃	—	—	9.4
S14		22		17		21.7	2.68	1.82	0.47	—	〃	—	—	10.1
S15				26		19.2	2.68	1.84	0.46	—	〃	—	—	19.1
S16		24		25		22.6	2.68	1.79	0.50	—	〃	—	—	20.3
S17		26		21		24.8	2.68	1.74	0.54	—	〃	—	—	16.5
S18		28		24		25.0	2.68	1.74	0.54	—	〃	—	—	21.2
S19				30		24.5	2.68	1.76	0.52	—	〃	—	—	36.9
S20		30		30		24.2	2.68	1.79	0.50	-	〃	—	—	38.8
S21		32		67		21.1	2.68	1.86	0.44	—	〃	—	—	119.5
S22		33.6		31		26.9	2.68	1.77	0.51	—	〃	—	—	43.3
S23		34		32	Gr sandy loam (ML)	20.0	2.69	1.71	0.57	—	〃	—	—	48.4
S24		36		47		23.5	2.69	1.75	0.54	—	〃	—	—	97.2
S25		38		36		23.6	2.69	1.77	0.52	—	〃	—	—	66.3
S26		40		62		20.2	2.69	1.86	0.45	—	〃	—	—	141.8

Sampler: 2in Splet Spoon G.W.L. : -1.85 m from G.L. Date : Nov. 21~22 '64

Boring No. B3

Boring					Soil Tests									
Sample No	Elevation (m)	Depth (m)	Log	N	Soil Classification	Natural Water Content %	Specific gravity	Dry Density gr/c.c.	Void Ratio	L.L. (%)	P.L. (%)	P.I. (%)	qu T/SF	qa T/SF
	+3.10	0 0.9			Gr. fine and sand (SP)									
S1		2		▽ 5	Gr. fine and sand (SM)	19.2	2.66	1.74	0.52	—	Np	—	—	0.5
S2		2.9 4		0	Gr sand dry loam with shell (ML)	29.8	2.69	1.52	0.79	—	〃	—	—	0.5
S3				1		28.3	2.69	1.54	0.75	—	〃	—	—	0.8
S4		5.6 6 6.6		4½	Gr. sandy loam with shell (SM)	26.8	2.68	1.67	0.61	—	〃	—	—	1.3
S5		8		15	Gr. fine sand with shell (SP)	17.6	2.66	1.93	0.38	—	〃	—	—	1.8
S6				17½		20.8	2.66	1.79	0.49	—	〃	—	—	4.8
S7		9.9 11.2		11	Gr. sand with (SM)	17.8	2.68	1.94	0.38	—	〃	—	—	3.3
S8		12 12.3		16	Gr. silty loam (ML)	21.7	2.69	1.64	0.64	—	〃	—	—	5.6
S9		14 14.2		17	Gr. sandy loam (SM)	20.7	2.68	1.79	0.50	—	〃	—	—	6.6
S10				18	Gr. fine sand (SM)	22.6	2.68	1.75	0.53	—	〃	—	—	8.2
S11		16		15		19.5	2.68	1.81	0.48	—	〃	—	—	2.0
S12		18		17½		15.7	2.68	1.96	0.37	—	〃	—	—	9.2
S13		20		16		21.9	2.68	1.78	0.51	—	〃	—	—	8.9
S14		22 22.2		18		20.0	2.68	1.88	0.43	—	〃	—	—	11.3
S15		23.1		16	Gr. sandy clay loam (ML)	22.6	2.69	1.74	0.54	—	〃	—	—	10.2
S16		24		37	Gr. sandy loam (SM)	20.9	2.68	1.83	0.46	—	〃	—	—	44.4
S17		26 26.6		28		19.2	2.68	1.89	0.42	—	〃	—	—	27.4
S18		28 28.3		31	Gr. loam (ML)	27.7	2.69	1.64	0.64	—	〃	—	—	35.8
S19				29	Gr. silg loam (ML)	27.9	2.69	1.65	0.63	—	〃	—	—	32.1
S20		30		38		23.4	2.69	1.76	0.53	—	〃	—	—	58.5

Reference-4.3 Earthquakes in Taiwan

(1) From the chronicle of big earthquakes in Japan and neighbouring districts, Scientific Almanac, Tokyo Astronomical Observatory, Japan.

No.	Date	Place	Note
187	1656 Jan. 10	Taiwan	
234	1720 Oct. 31	"	Many destroyed and killed
242	1736 Jan. 29	"	Many killed
246	1754	"	
253	1776 Dec. 11	Chiai	Many destroyed and killed
259	1792 July 20	"	100 killed
271	1815	I-Lan	
272	1816	"	Many destroyed
286	1839	Taiwan	Land slided, houses destroyed
292	1848	"	Houses destroyed
309	1862 June 8	Chiai, Changhwa	Many destroyed and killed
312	1867 Dec. 18	Taiwan	Keelung totally destroyed, tsunami attacked
322	1892 Apr. 22	Anping	Many destroyed
349	1904 Nov. 6	Touliu, Chiai	611 totally and 1112 partially destroyed, 11 killed
352	1906 Mar. 17	Chiai	1258 killed, 745 heavily injured, 6769 totally and 3633 partially destroyed, many faults
353	1906 Apr. 14	Chiai, Yenshuichiang	1794 totally and 2116 partially destroyed, 60 killed
357	1909 Apr. 15	Taipei, Keelung, Taoyuan, Shengkeng	204 destroyed, 60 killed
370	1916 Aug. 26	Nantou	100 totally destroyed, 180 killed and injured
372	1917 Jan. 5	Pulishe	130 totally destroyed, 50 killed
377	1920 June 5	Middle of Taiwan	2 killed
380	1922 Sept. 11	Taipei, Hsinchou, I-Lan	5 killed, 25 totally destroyed
387	1927 Aug. 25	Yenshuichiang	9 killed, 27 injured
391	1930 July 8	Tsengwen, Hsinying	297 totally destroyed, 5 killed. 72 totally destroyed by the aftershock on 22th
394	1935 Apr. 21	Hsinchu, Taichung	3276 killed, 12053 injured, 17907 totally destroyed, 11405 partially destroyed, 9806 damaged. 43 killed by the aftershock on 17th Apr.
408	1941 Dec. 17	Chiai	319 killed, 1768 totally destroyed

(2) From the chronicle of big earthquakes in the world, Scientific Almanac, Tokyo Astronomical Observatory, Japan.

Date	M	Place
1902 Mar. 20	7.3	Tainan
1903 June 7	7.8	I-Lan
1904 Nov. 6		Touliu, Chiai
1935 Apr. 20	7.1	Hsinchu, Taichung. 120.8°E, 24.3°N
1937 Dec. 8	7.0	Northeast off Taitung. 121.5°E, 23°N

(3) From the chronicle made by Taiwan Provincial Weather Bureau

Date	Place	Note
1655 Jan. 21	Tainan	
1660	"	
1720 Oct. 31	"	Many destroyed and killed
1721 Jan. 5	"	
1736 Jan. 29	Tainan, Chiai, Changhwa	Many killed
1754 Apr.	Tanshui	
1776 Dec.	Chiai	Many destroyed and killed
1792 July 20	Chiai, Changhwa	100 killed
1815 July	I-Lan	
1815 Oct.	Tanshui	
1816	I-Lan	Many destroyed
1833 Dec.	"	
1839	Chiai	Many destroyed, land slided
1840 Nov.	Yunlin	Land slided
1848	"	Many destroyed
1850	Chiai	
1862 June 5	Tainan, Chiai, Changhwa	Many destroyed and killed
1867 Dec. 18	Keelung	Houses flown out, hundreds persons drowned by tsunami
1881	Taipei	Many destroyed and killed
1892 Apr. 22	Tainan, Anping	Many destroyed
1896 Feb. 12	I-Lan	

Reference-4.4 Seismicity of Taiwan

(summarized from Hsu Ming-Tung, Chief, Observation Division, Taiwan Provincial Weather Bureau, "Seismicity of Taiwan", 1965)

Taiwan lies on the Circum-Pacific Seismic Zone and has a seismic network of 16 stations (Taipei, Anpu, I-Lan and Hsinchu in northern district; Taichung, Alishan and Yushan in Taichung district; Tainan, Penghu and Kaohsiung in Tainan district; Hengchun and Tawu in Hengchun district; Taitung, Hsinchiang and Lan Hsu in Taitung district; Hwalien in Hwalien district).

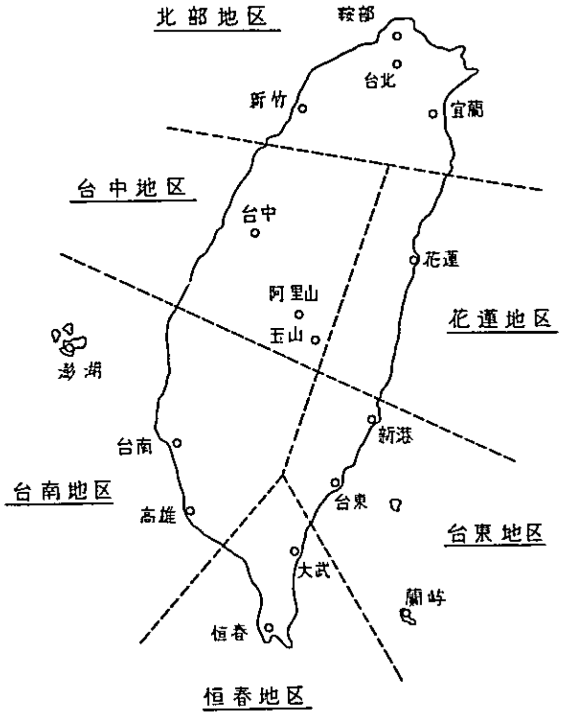


Fig. 4-10 Earthquake Observation Network

Taiwan experienced earthquakes about 1,269 times on a yearly average during the years from 1930 to 1961. Out of them 1,035 were unfelt earthquakes and 234 felt. The maximum number of occurrence was recorded in 1951, amounting to 3,726 times including the after-shocks of the earthquake of Hwalien and Taitung, and the second largest one amounted to 3,224 times being caused by the earthquake swarms near Suau, northeastern coast of Taiwan. The minimum was only 264 times in 1910.

As to the geographical distribution, the largest number of felt earthquakes was observed at Hwalien district, amounting to 123.2 times on the yearly average from 1913 to 1961. This value represents 44% of the total felt earthquakes in Taiwan. The largest number of unfelt earthquakes also occurred in the same district, amounting to 392.3 times per year from 1930 to 1961, that is, 37.9% of the total. In the west plain near Hsinchu and Chiai area earthquakes also frequently occur and the quietest area is the southwestern part of the island.

In case of an earthquake occuring in the Eastern Zone whose epicentre is located on land, its magnitude is comparatively small, and the depth of hypocentre is about 10 to 30 km, but it occurs frequently and continuously. In case the epicentre is located at sea, its magnitude is larger, sometimes the Gutenberg-Richter's M scale reaching near 8, and the depth of hypocentre is deeper, namely 50 to 200 km, so that little damage and crustal deformation occur on land.

In the Westside Zone, owing to the depth of the hypocentre being very shallow, that is 0 to 10 km, a great damage accompanying fault, failure, landslide, etc. has frequently been experienced.

The remarkable earthquake (M is bigger than 6.4 and the radius of felt area is greater than 300 km) occurred 53 times during 1900 ~ 1961 and frequently along the east coast and Chiai area. The number of the moderate earthquake (M=5.7~6.4, r=200~300km) amounted to 152 during 1900~1961, and the district of their frequent occurrence was also along the east coast and Chiai area. The number of the earthquake of limited area (M=4.8~5.7, r=100 ~ 200km) amounted to 617 during 1930~1961 and the area of its most frequent occurrence was off the coast of Hwalien. The local earthquake (M is smaller than 4.8, r is less than 100km) occurred 6,662 times during 1930~1961.

A formula has been found to express the relation between N which stands for the number of occurrence of Remarkable, Moderate, Limited area and Local earthquake and its representative radius of felt area r (measured in km) which is 350, 250, 150 and 50km respectively.

$$\log N = 8.38 - 2.63\ r$$

Another formula has been found useful for calculating the Gutenberg-Richter's magnitude scale of an earthquake occuring in or near Taiwan from the seismometrical data at Taipei.

$$M = \log a + 2.24 \log \triangle - 1.77$$

where M is the magnitude, a is the maximum displacement amplitude of the ground due to that earthquake (measured in micron) observed at an epicentral distance $\triangle$ (measured in km).

Some of the earthquakes of the order of 7 to 8 which occurred off the east coast caused seismic sea wave (tsunami), but not sufficient to cause damage since 1896, when seismological observation began. But, according to Davidson, there occurred a great earthquake off Keelung on December 18, 1867, accompanying severe seismic sea waves and causing a great damage with several hundreds persons drowned.

The earthquakes by which damage was caused in Taiwan during 1900 to 1964 have amounted to 72, of which 18 earthquakes have brought about more than 100 casualties or more than 1,000 houses totally destroyed or damaged. The earthquake which resulted in the greatest casualities in Taiwan was the Hsinchu-Taichung earthquake in 1935 by which 3,276 persons were killed and 12,053 hurt, and 17,909 houses were totally destroyed and 36,781 damaged. The next was the Chiai earthquake in 1906 by which 3,643 persons were either killed or hurt and 20,987 houses were destroyed. The recent strong earthquake occurred in the Tainan-Chiai area on January 18, 1964, by which 756 persons were killed or hurt and 15,808 houses were destroyed.

The epicentre of disastrous earthquakes is mostly located on the east coast of Taiwan and the west plain near Hsinchu and Chiai area. There appears a remarkable feature in the epicentral region of disastrous earthquakes, that is, the repeated occurrence. For instance in the Chiai area, out of the 18 large earthquakes 7 have occurred almost in the same region during the past 60 years. In such places the earthquake-proof construction must be payed special attention to.

The annual mean of the number of 4 grade earthquake (strong, 25~80 gal), 5 grade (very strong, 80~250 gal) and 6 grade (disastrous, larger than 250 gal) is shown in the following table. The period of statistic data used is not uniform, the longest being 44 years and the shortest 25 years.

Place	4 grade	5 grade	6 grade
Taipei	0.41	0.05	0.00
Hsinchu	0.08	0.08	0.00
Taichung	0.11	0.02	0.00
Penghu	0.00	0.00	0.00
Alishan	0.19	0.00	0.03
Tainan	0.14	0.02	0.00
Kaohsiung	0.06	0.00	0.00
Hengchun	0.05	0.07	0.00
Tawu	0.14	0.00	0.00
Taitung	0.36	0.05	0.02
Hsinchiang	0.25	0.00	0.04
Hwalien	1.18	0.25	0.02

7. Future Investigation Programme

7.1 Investigation programme

(1) Littoral drift

A. Wide range sounding : In a zone of about 21km long (Shoushan～Fengming) and 4km wide. Twice a year (between winter monsoon season and summer typhoon season). The interval of survey line is 500m in general and 100m in a zone of 6km long and 2.5km wide around the proposed site of the second entrance.

B. Transverse sounding on selected lines : On six lines at every 3km from the proposed site of the second entrance and at the eroded beach of Hungmaochiang. Once every one or two months.

C. Bottom material sampling : On three lines out of the above-mentioned six transverse lines. Twice a year. At every 100m up to -10m and every 500m beyond -10m.

In addition to that, sampling at eight spots around the existing harbour entrance is also proposed after the typhoon season of this year.

D. Neighbouring coast survey: In order to obtain the definite tendency of the littoral drift, it is required to observe continuously the beach and estuary processes and effect of structures (breakwaters, groins, seawalls, etc.) between the Tsengwen-chi and Kaoping-chi at least every two months or immediately after remarkable typhoons or floods.

(2) Wave

A. Wave observation : At the water depth of about 12m (nearly 1.4km off the proposed site of the second entrance). With a pressure-type or step-resistance-type wave-height meter. Eye-observation of wave direction, especially in the period of typhoon, is also necessary.

B. Wave estimation : Comparison of estimated values from meteorological data with actually observed data. After having identified the accuracy of the hindcasting method in Kaohsiung coast, the method is to be applied to the past eminent typhoons so as to determine the design wave.

It is also useful to compare the estimated values of the neighbouring coast with the actual status of the stability of structures or wave overtopping in order to get a quantitative idea of wave action.

(3) Tidal current : Observations of the tidal current passing through the existing entrance channel and the second entrance as basic data for obtaining its influence on the water depth maintenance of the fairways or on the water pollution in the harbour. Although it is difficult to establish any definite method, observations, computations and collection of examples in comparable harbours should be tried.

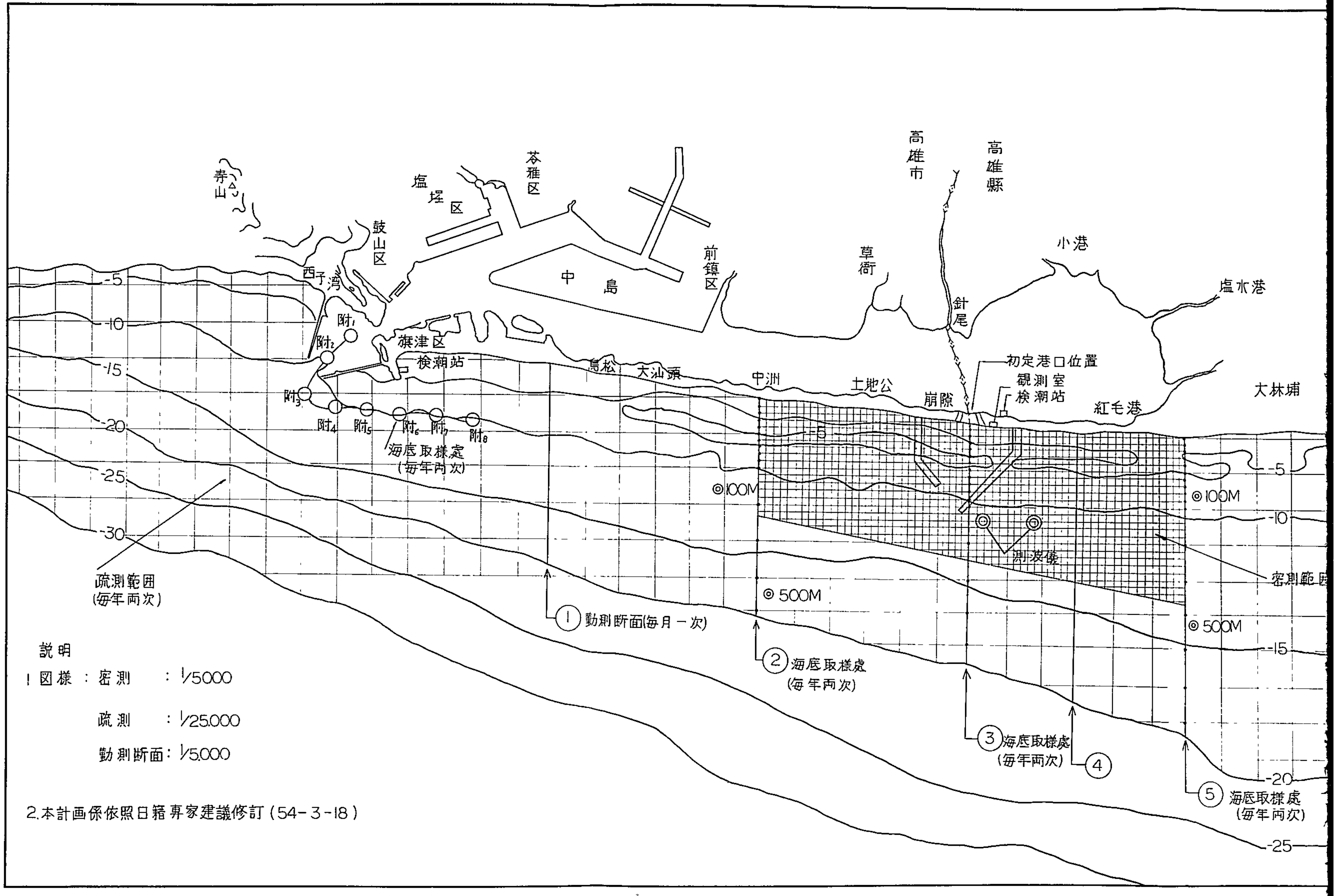
(4) Alignment and cross-section of new breakwaters : Model experiments related to the layout with a scale of about 1/100 and to the design of cross-section with a scale of about 1/30 are proposed. In order to solve any problems presented at any stage of the construction work, it is recommended to keep the experimental facilities until the breakwater is completed.

7.2 Plan and schedule of investigation programme

Fig-4.11 is a plan of the programme and Table-4.16 is its schedule.

1965年3月編製

年月 / 工作項目	1965年									1966年					
	4月	5月	6月	7月	8月	9月	10月	11月	12月	1月	2月	3月	4月	5月	6月
沿岸三角点 控制点測量	—														
沿岸地形測量		—													
浚渫深浅測量	—	—	—					—	—				—	—	
原港口第二港口採取底質 勘測深浅測量			—		—	—		—	—		—	—		—	—
海岸線測量							—				—	—			
潮高観測				—	—	—	—	—	—	—	—	—	—	—	—
内港地形深浅測量				—	—	—									
隣接海岸線踏勘			—		—		—		—		—		—		—



說明

1 図様：密測 ：1/5000

疏測 ：1/25,000

勤測断面：1/5,000

2.本計画係依照日籍專家建議修訂(54-3-18)

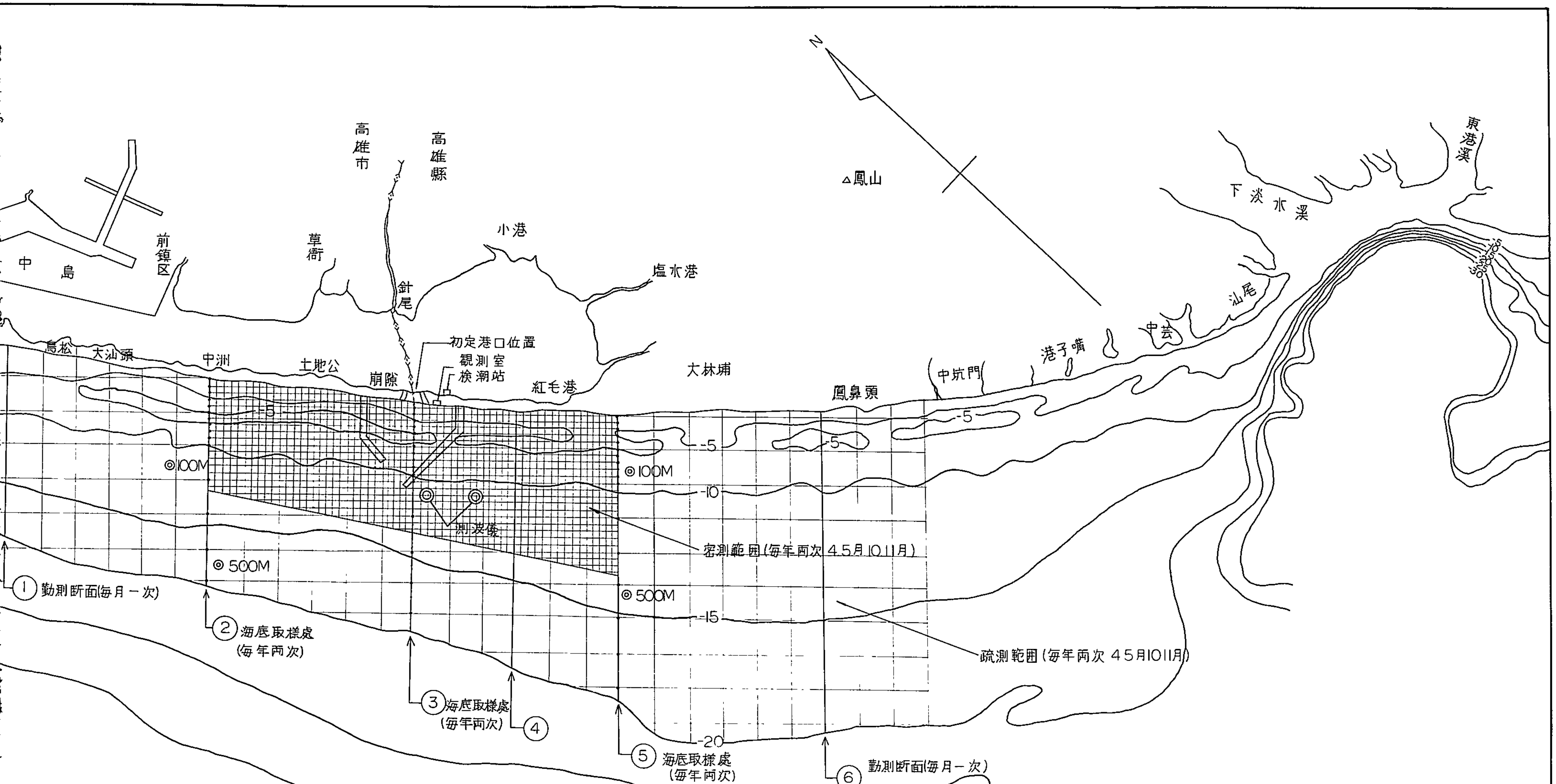


Fig. 4-11 高雄港第二港口測量調査計画図

CHAPTER V

COMPARISON OF STRUCTURAL TYPES OF BREAKWATER

1. Summary

In this chapter will be made a comparison of the structural types of breakwater on the basis of the data obtained in the survey.

The structural type of breakwater most widely employed is the composite caission type composed of concrete caissons on rubble foundations. This is adopted also in the original construction programme of the Kaohsiung Harbour Bureau.

In case of this type, concrete caissons should be installed at a designated place on calm days and then stuffed with some proper fillers in order to fix them against a certain magnitude of waves with a specified frequency. The filler consists either of rubbles or lean-mix concrete.

There is a structural type in which ripraps are covered with tetrapods. Although this type enables the construction work even in the case of fairly strong waves, it has such disadvantages as require constant maintenance and repairing works as well as a large quantity of materials.

Under specified design conditions a rough design will be worked out, and construction cost will be estimated for each of the three types: The breakwater with rubble-stuffed caissons, the one with concrete-stuffed caissons and the tetrapod type.

2. Design conditions

The design conditions for the structure of breakwater are presumed tentatively as follows:-

i) Layout of breakwater : same as the original plan of Kaohsiung Harbour Bureau. (Fig. 5-1)

ii) Design water level : H.W.L. = +1.10 m
L.W.L. = ±0.00 m

iii) Offing wave height : 6.0 m (presumed incident upon breakwater at a right angle)

iv) Design wave height and top height of breakeater

Water depth (m)	-1.00	-3.00	-5.00	-6.50 ~ -12.00
Design wave height (m)	1.70	3.30	4.90	6.00
Top height of breakwater	+3.50	+3.50	+4.50	+5.50

v) Length of breakwater classified by water depth

Water depth	-1.00	-3.00	-5.00	-7.00	-9.00	-11.00	Total
South breakwater	250	250	300	300	350	350	1,800 m
North breakwater	200	180	270	300	250	-	1,200 m
Total	450	430	570	600	600	350	3,000 m

3. Design for caisson type breakwater

The structure of the caisson type breakwater is designed as follows:-

i) The thickness of the foundation ripraps should be 1.5m on the average in order to level off the unevenness of the foundation and distribute the upper load.

ii) The top height of the caisson should be H.W.L. + 0.90m = +2.00m in view of the efficiency of the work execution.

iii) Concrete should be placed as high as +3.50m on the top of the caisson, whose outer side should be equipped with a parapet of the designed heights.

iv) Two kinds of filler materials are conceivable : rubbles and lean-mix concrete. The width of the caisson is determined by the stability conditions according to the respective circumstances.

v) Two rows of concrete blocks should be arranged outside the caisson, and a row inside in order to consolidate its front footing. The side slope of the ripraps is covered with great lumps of stone.

vi) Caissons will not be used for the shallow part of less than -3m, but a riprap structure will be employed. This work is started from the shore at the outset, and continued successively along the executed portion.

vii) The above design conditions will give the cross-section of the caisson type breakwater as follows:-

unit: metre

Water depth			-5.00	-7.00	-9.00	-11.00
Top height of foundation ripraps			-3.50	-5.50	-7.50	- 9.50
Top height of caisson			+2.00	+2.00	+2.00	+ 2.00
Top height of crown concrete			+3.50	+3.50	+3.50	+ 3.50
Top height of parapot			+4.50	+5.50	+5.50	+ 5.50
Size of caisson	height		5.50	7.50	9.50	11.50
	length		15.00	12.50	12.50	12.50
	width	rubble-stuffed	15.50	20.00	20.00	20.00
		concrete-stuffed	14.00	17.50	17.50	17.50

4. Design for tetrapod type breakwater

The structure of the tetrapod type breakwater is designed as follows:-

i) The standard gradient of the outside slope should be 1:4/3. It is covered with two layers of tetrapods with weights listed below.

Depth of water (m)	-3.00	-5.00	-7.00	-9.00	-11.00	Head of breakwater
Weight of tetrapod (t)	8	16	32	32	32	40

ii) Inside the tetrapod layers are arranged great lumps of stone, each of which weighing 1 ~ 2 t, in three rows, and the innermost stuff consists of small lumps (30 ~100 kg. each)

iii) The width of the top surface is about 15m.

iv) Fascine mattresses are laid at the toe of the slope in order to arrest the subsidence of the tetrapods.

v) Great lumps of stone are employed to protect the footing where the water depth is less than the design wave height.

vi) Concrete should be placed on the top of the breakwater as high as +3.50m and as wide as 11.0m and a parapets of the designed heights should be equipped outside.

vii) The inside slope should be covered with great lumps of stone; its upper part with stones of 5 t each, and lower part with those of 1 t each for the prevention of erosion caused by overtopping waves.

5. Quantity of construction work and necessary machinery

Based on the above-mentioned cross-section and the length classified by water depths, and also by the application of a proper extra percentage to each item of the construction works, the quantity of the principal works will be as follows:-

Table 5-1 Quantity of construction work

	Caisson type (rubble-stuffed)	Caisson type (concrete-stuffed)	Tetrapod type
Rubble (m^3)	524,000	265,000	795,000
transported by land	394,000	135,000	245,000
transported by sea	130,000	130,000	550,000
Concrete (m^3)	184,000	386,000	231,000
cast in yard	110,000	99,000	231,000
cast in place	74,000	287,000	-
Levelling-off (m^2)	155,000	149,000	227,000
above water	20,000	20,000	67,000
under water	135,000	129,000	160,000

By assuming the requirements for the execution of works as the following, an estimate of the necessary machinery is given in the list below. If the execution period of works is assumed to be five years, the machinery will have to be considerably increased.

i) Execution period of works   7 years, of which a year is the preparatory work period.

ii) Workable day per year

land machinery.................................... 270 days

work vessels...................................... 210 days

iii) Operational rate of work vessel........................ 2/3

Table 5-2 Quantity of machinery

Name of machine	Capacity	Caisson type (rubble-stuffed)	Caisson type (concrete-stuffed)	Tetrapod type
Tugboat	500 PS; 90t	1	1	-
"	120 PS; 30t	3	7	1
Pontoon	100t; on deck loading	3	7	1
Transport barge	self-propelling; hopper-barge; loading 500 m³	10	4	4
Floating crane	20t load; non-propelling	1	1	-
Concrete-mixer ship	equipped with 2 mixers of 0.6m³; hopper of 60 m³	1	3	-
Derrick barge	5t load; non-propelling	3	5	2
Dump truck	15t load	4	4	18
Bulldozer	15t	4	3	1
Truck crane	5 ~ 10t (load)	2	2	10
Shovel loader	1.2 m³	2	1	3
Yard crane	5t load; 30m lift; travelling	1	1	-
Vibrator	rod-type; engined	11	7	14
Mixing plant	0.8 m³	1	1	2
Pump	3in centrifugal; engined	1	5	-
Jib crane	20 ~ 40t load	-	-	1
Trailer	40t load	-	-	4

In addition, the following are necessary for the manufacturing yard of caissons or tetrapods:-

o Caisson yard

capacity   capable of manufacturing 3 caissons at a time

temporary storage yard

for rubble-stuffed .... 14,000 m²

for concrete-stuffed .... 13,000 m²

o Tetrapod yard

casting yard .... 800 m²

temporary storage yard .... 8,000 m²

6. Construction cost of breakwater

A rough estimate of the construction cost of the three types of the breakwater is listed below.

In case that the execution period is five years, equipment cost of machinery and others will have to be increased, but, on the other hand, there will be such advantages as the early availability of the harbour, reduction of interest on the construction cost, etc.

Table 5-3 Construction cost of breakwater

(unit: millions of NT$)

	Caisson type (rubble-stuffed)	Caisson type (concrete-stuffed)	Tetrapod type
construction cost	330	370	360

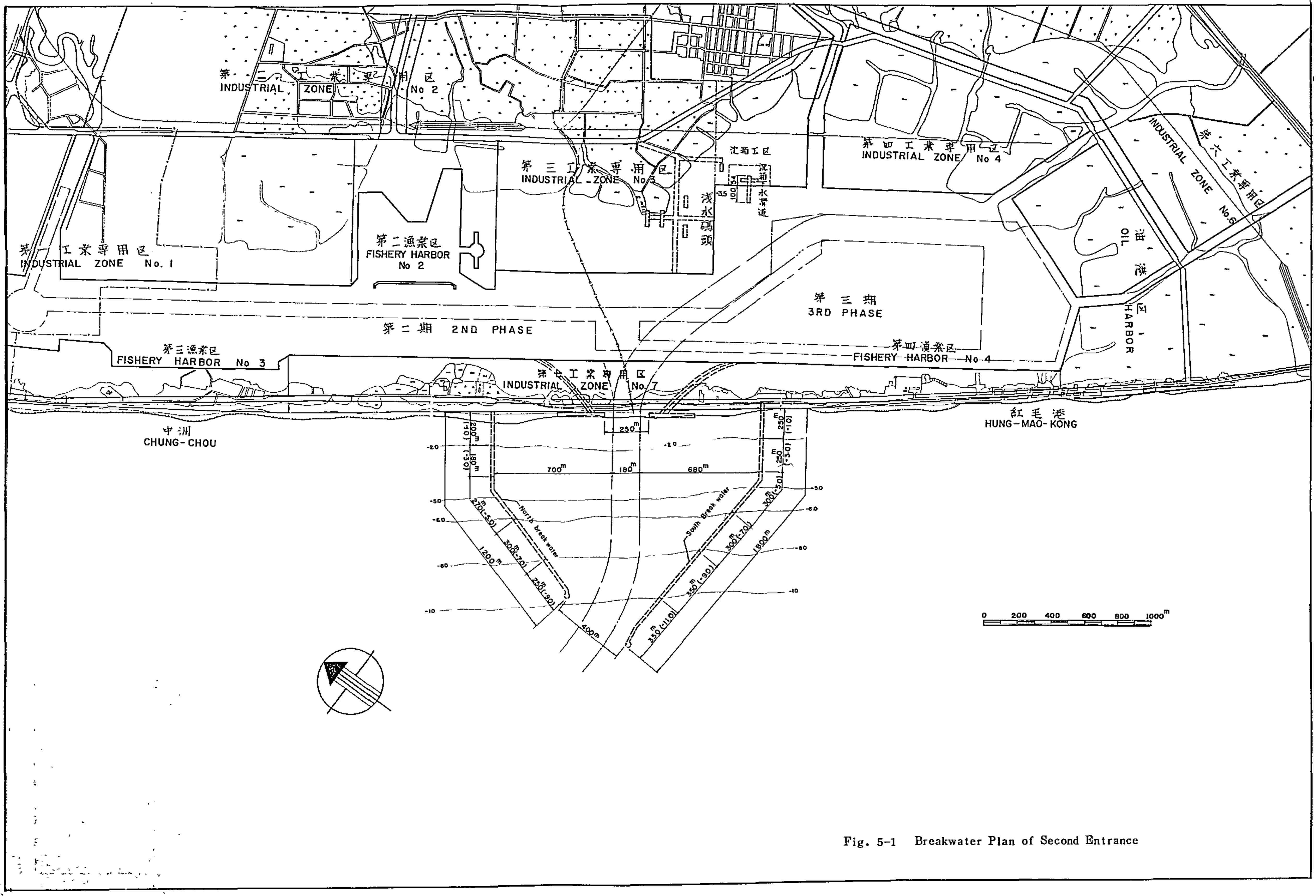


Fig. 5-1 Breakwater Plan of Second Entrance

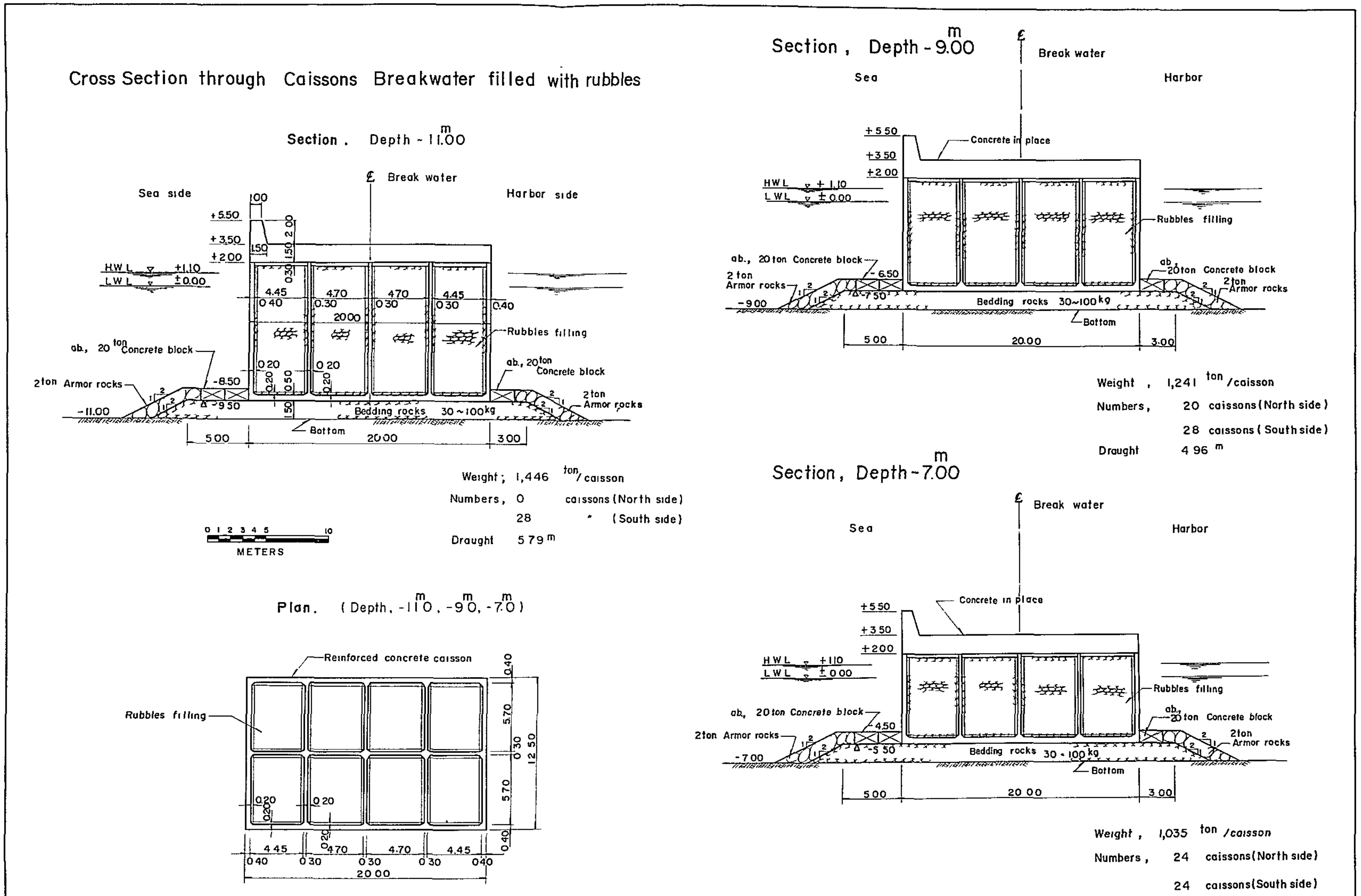


Fig. 5-2-1 Rubble-Filled Caisson Breakwater (1)

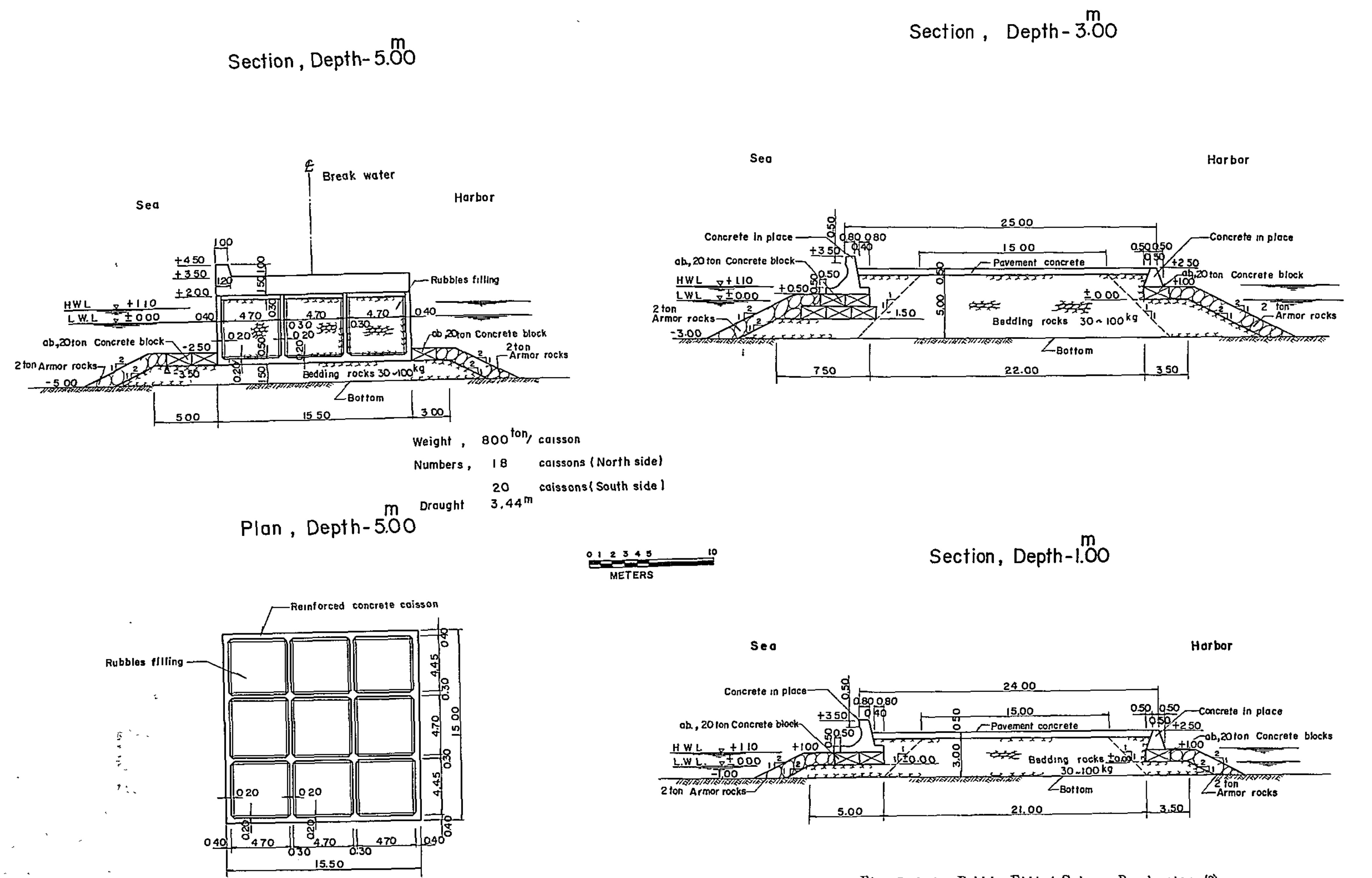
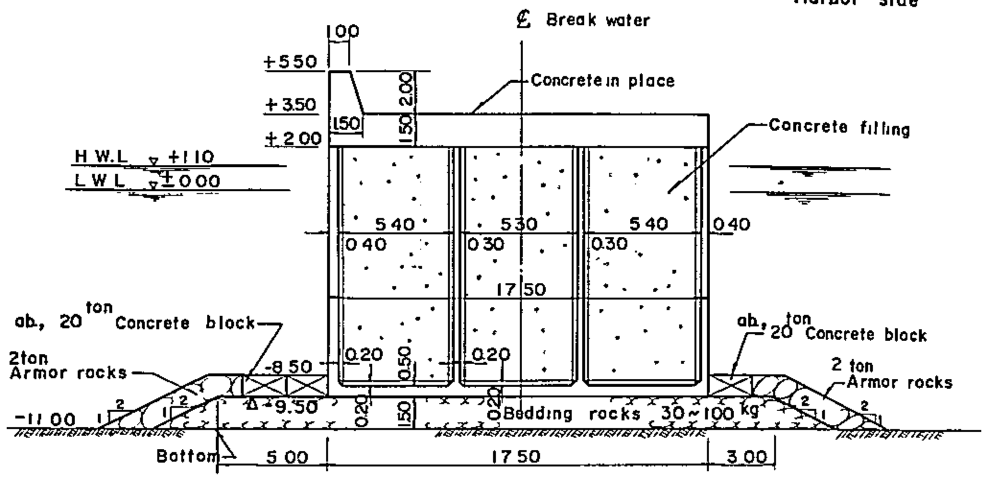


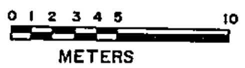
Fig. 5-2-2 Rubble-Filled Caisson Breakwater (2)

Cross Section through Caissons Breakwater filled with concrete

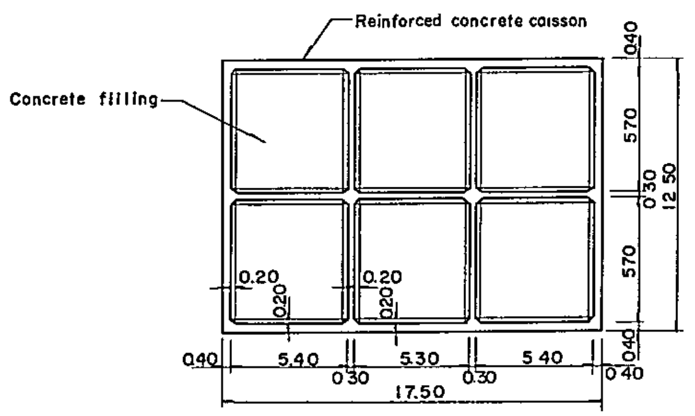
Section , Depth − 11.00 m



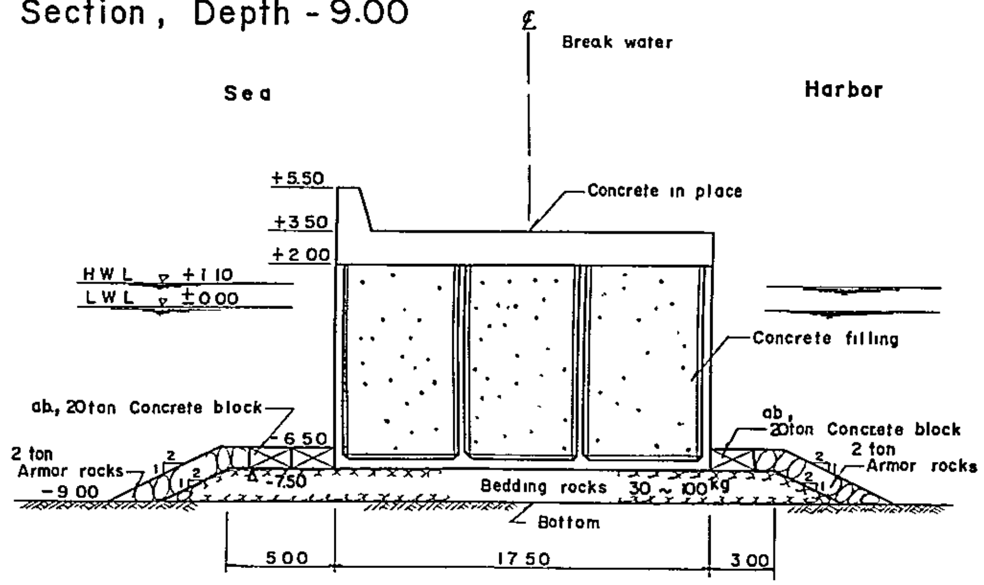
Weight ; 1,236 ton/caisson
Numbers ; 0 Caissons (North side)
28 Caissons (South side)
Draught 5.65 m



Plan. (Depth ; -11.00 m, -9.00 m, -7.00 m)

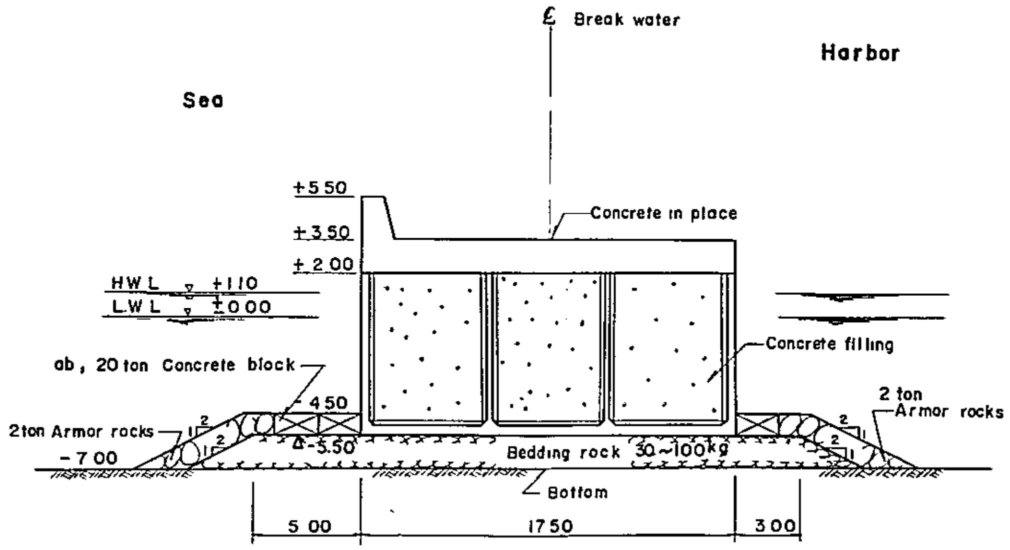


Section , Depth - 9.00 m



Weight 1,061 ton/caisson
Numbers 20 caissons (North side)
28 caissons (South side)
Draught 4.85 m

Section , Depth - 7.00 m



Weight ; 886 ton/caisson
Numbers ; 24 caissons (North side)
24 caissons(South side)
Draught 4.05 m

Fig. 5-3-1 Concrete-Filled Caisson Breakwater (1)

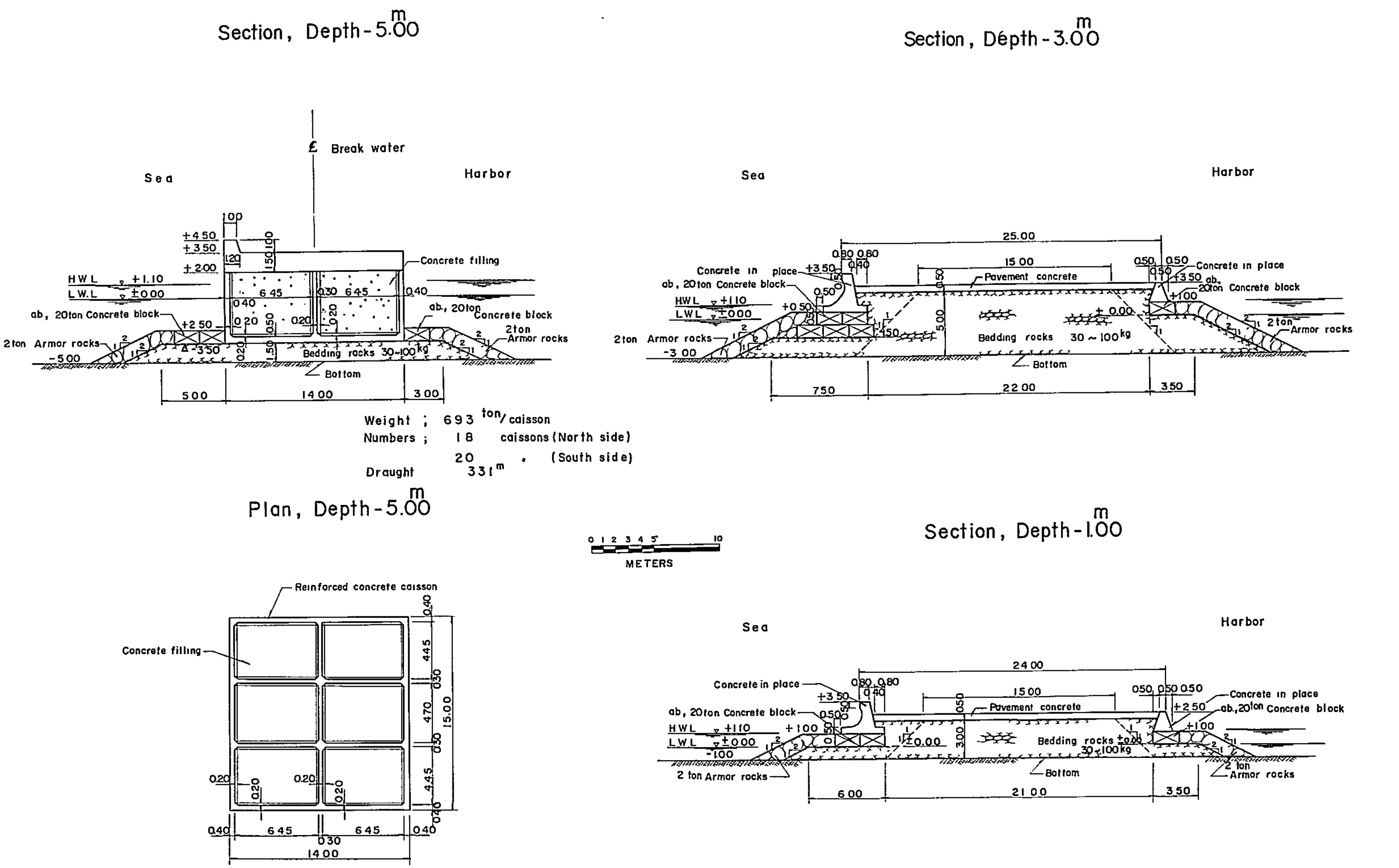
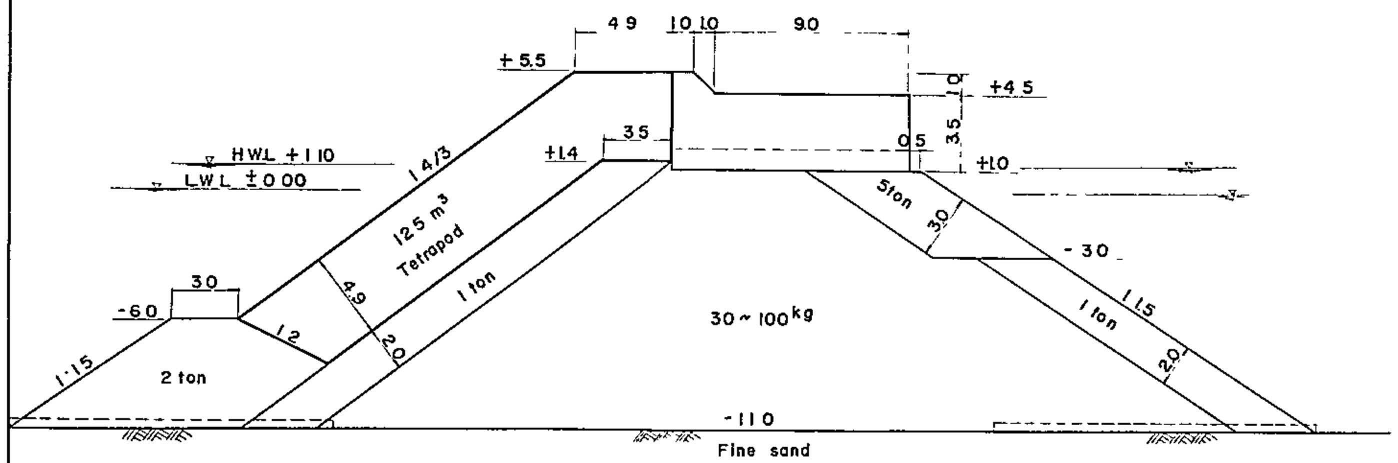


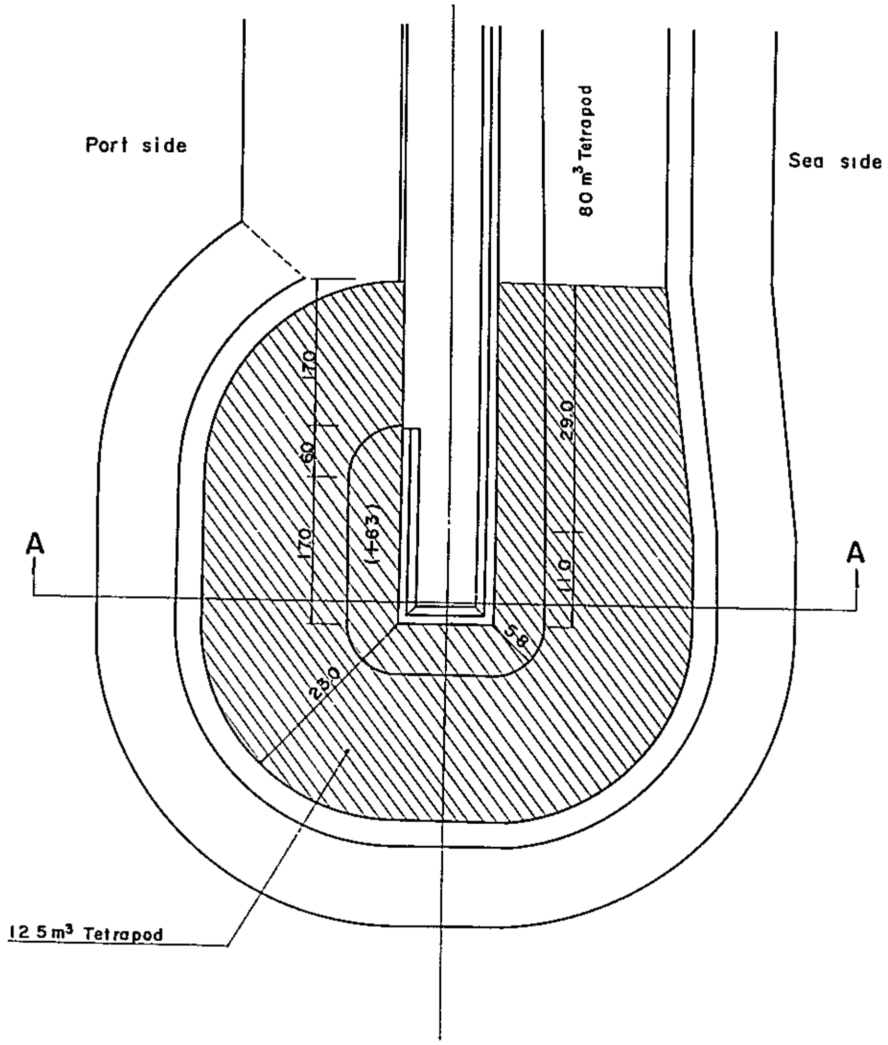
Fig. 5-3-2 Concrete-Filled Caisson Breakwater (2)

PORT KAOHSIUNG
STANDARD CROSS SECTION OF BREAKWATER
SCALE 1/200

Section, Depth - 11.00 m



PORT KAOHSIUNG
PLAN OF BREAKWATER HEAD
SCALE 1/500



Cross Section A-A

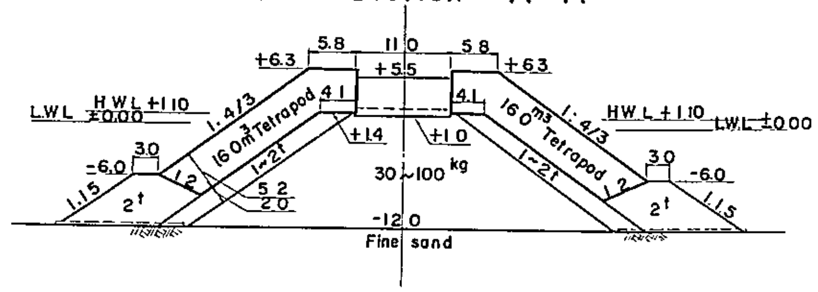


Fig. 5-4-1 Tetrapod Breakwater (1)

PORT KAOHSIUNG
STANDARD CROSS SECTION OF BREAKWATER

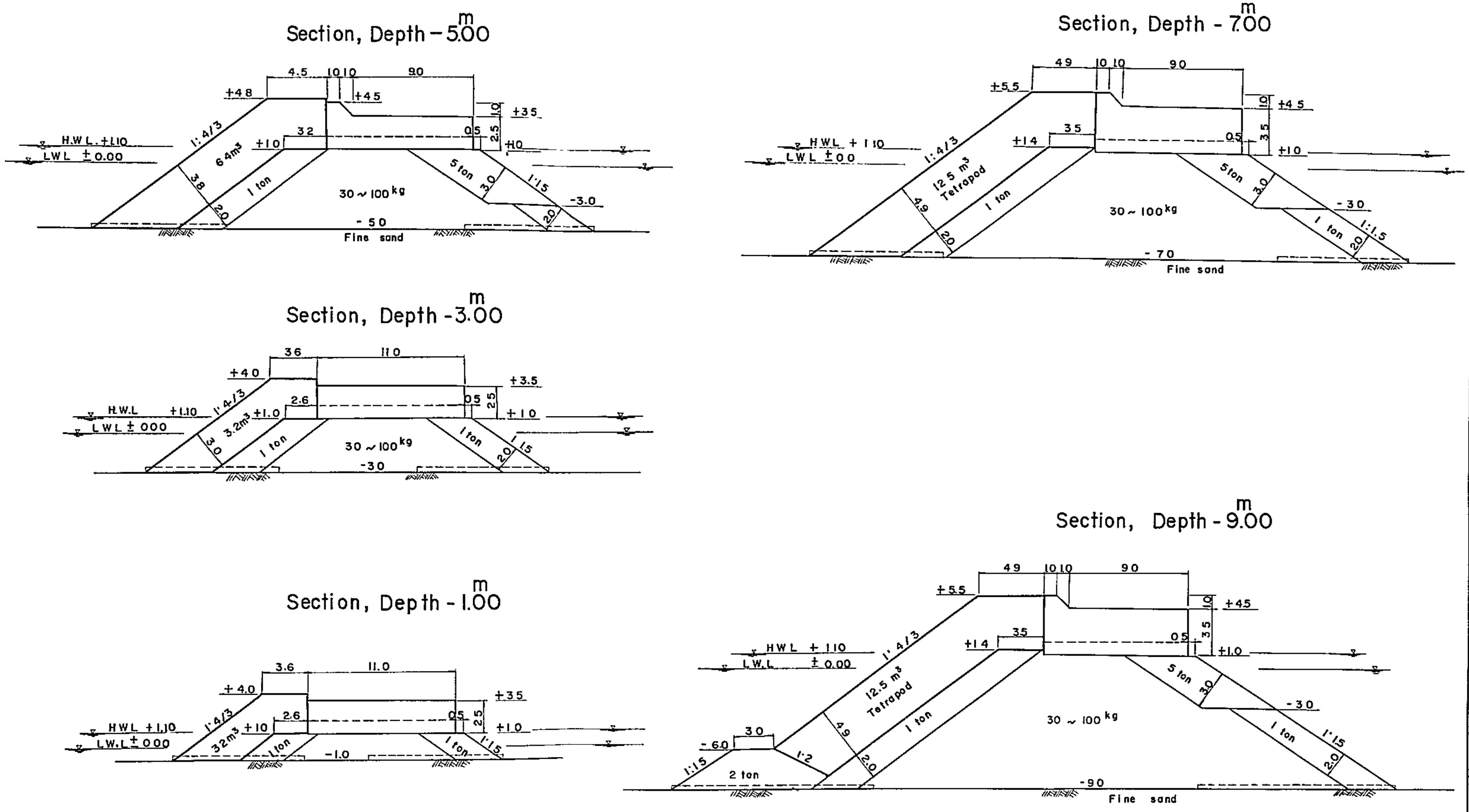


Fig. 5-4-2 Tetrapod Breakwater (2)