CHAPTER 86

Study of Shelf Waves vs Sand drift in NW coast of Taiwan

by

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ABSTRACT

For the planning and design of harbor and coastal Engineering, most important affected factors are waves and littoral drift.

This research deals with analysis of the measured waves and the budget of the beach material whether it is deposited or scoured in the North-western coast of Taiwan; and the relationship between wave energy and littoral transport rate. For processing this research the field Survey wave measurement, sand sampling, and echo sounding is necessitated. The objective of this research is to establish the model of waves and littoral transport budget. Therefore, the results of this research are planned to submit to the planning and design of harbor and coastal engineering works of the Taiwan west sandy coast.

The main contains of this research are consisted of

(1) Analysis, observations and investigations of the field oceanographic data, winds, waves, coastal geomorphology and littoral drift of the North-western coast of Taiwan.

(2) Analysis of the shelf waves from the actual measured wave records.

(3) Research of the wave decaying process of the continental shelf waves.

(4) Statistical research of the measured waves and establishment of the practical model of the relationship between the shelf wave energy and the littoral transport rate in the north-west coast of Taiwan.

(5) Plotting time history of significant wave heights and significant wave periods in the Taiwan Strait.

1. Introduction

Based on the wave pattern, the geographical location and the disposition of rivers, the littoral drift moves predominantly from NE to SW direction in section I as shown in Fig. 1. Seven rivers of rapid stream bring tremendous amount of sediments from the high mountain to the nearshore of this section in typhoon season (i.e. from June to September). But for the winter monsoon season, i.e. from October to the next April, the waves induced by NE monsoons migrate littoral drift from north toward south.

Applying the energy approach for unidirectional steady flow derived by Bagnold (1963), the theoretical relationship between the littoral immersed weight transport rate and the alongshore breaking wave energy is found out. It reveals that the relationship is not strictly linear, i.e. the larger part of the alongshore breaking wave energy is supplied for transporting the sediment as the former increases. But for a coast having a steady oceanographical condition, the relationship could be considered as linear relation since the alongshore breaking wave energy is not varying very much.

By using the shelf wave records and the littoral drift quantity obtained from long-term echo-sounding map, the relationship between alongshore breaking wave energy and littoral immersed weight transport rate is found out.

2. Information of Oceanographical Data

For the movable-bed investigation of Lin-Kou Power Plant (Located in the NW coast of Taiwan), the following field investigation is undertaken.

1) Wind & Waves: The monsoon of this area starts from September to April of the next year, the prevailing wind direction is NE-ENE, and the wave direction of the nearshore is NNE, the maximum wave height of strong monsoon is 4M, while the wave period is 9.0 sec. The maximum significant wave height of hurricane attacking $H_{1/3}$= 4.75M, the corresponding period $T_{1/3}$= 12 sec.

2) River sediment discharge: The sediment which affects obviously on the Lin-Kou Power Plant is from the Tansui River, the river sediment transport rate is 6.095 x 10^6 MT/year.

3) Littoral transport: Based on the sounding data of Lin-Kou coastal area, including survey maps of 1971, 1975, 1977, 1978 and 1983; and the sand sampling data, it is recognized that sediment transport toward south.

a) Coastal morphology: The mean beach slope of nearshore none is 1/66, the sea-bed slope of depths from -15M to -20M is 1/300, is flat, the profile near the intake structure is steeper than those of other profiles. Therefore, it is very clear that the effect of wave action is severe, the littoral transport is obvious as Fig. 2.2 shown.

b) Sediment particle: Based on the field measurement, the coastal area of this region spreads over the cobble stone, the distribution of sand particle after Sieve analysis is shown as Fig. 2. From the figure, the sediments of the breaking zone and inner shore zone of the power plant area d_{50}= 0.3-0.4 m/m, while contour of -5M to -10M, d_{50} is 0.2 m/m, therefore the sand particle of the upstream of the plant site is bigger than that of the downstream site, it is recognized that the littoral transport direction is from north to south, as shown in Fig. 2.3.

c) Littoral transport rate: Based on the echo sounding data, using mesh method to calculate the littoral transport rate of the deposit sand around the coastal area of the plant site. It is 37.5 x 10^4 M^3/ year, and could be found out from Fig. 2.4.

d) Tide and tidal current: The tide is belong to semidiurnal tide. The mean high water level of the spring tide is 3.1 M, while the mean low water level of the spring tide is -0.3M. Tidal current is measured about 0.75 m/sec or so.

3. Statistical Analysis of Self Waves

Waves in Taiwan Strait, i.e. self waves, are to be divided into three patterns, i.e., waves in winter monsoon, waves in hurricane and waves generated by convective wind in the summer. Statistical characteristics of significant waves extracted from the meteorological and wave measuring records along the continental self for 4 years are shown in Fig. 3.1 (Tang, 1986).

Wave records obtained from cassette type wave meter are continuously measuring the whole year in the NW coast located in the nearshore area of Tou-Yuan Fig. 3.2, Fig. 3.3, Fig. 3.4, Show that relationship between wave period, wave height vs percent frequency in January (winter), in August (summer) and the whole year's record (all available data). While Fig. 3.5 shows that correlation between wave height and wave period in January and in September. Their range for wave height is from 20 cm to 4m, wave period is from 5 sec to 15 sec or more. The waves in the NW coast are slightly stronger than those of the mid-west coast of Taiwan.

4. The calculation of the alongshore breaking wave energy:

The wave is affected by the effects of shoaling, refraction, bottom friction and percolation. By neglecting the effects of bottom friction and percolation as wave is propagating toward the surf zone, there the breaking wave height is equal to

$$H = H_0 K_r K_s \tag{4.1}$$

where K_r and K_s are refraction coefficient and shoaling coefficient respectively. The mathematical representation is as follows

$$K_r = (B_0/B)^{\frac{1}{2}} \tag{4.2}$$

$$K_s = (C_{g0}/C_g)^{\frac{1}{2}} \tag{4.3}$$

where B is the separation of the wave rays and prefix "o" represents the characters of deep water. As the bottom slope is smaller than 1/10, then K_r and K_s could be calculated from the four equations derived by Chao, Y.Y. (1970) as follows

$$C^2 = \left(\frac{g}{k}\right) \tanh kh \tag{4.4}$$

$$\frac{d}{ds} = \frac{1}{c}\left(\sin\theta\frac{\partial c}{\partial x} - \cos\theta\frac{\partial c}{\partial y}\right) = -\frac{1}{c}\frac{dc}{dB} \tag{4.5}$$

$$H_0^2 (C_g)_0 B_0 = H^2 \cdot C_g \cdot B = \text{constant} \tag{4.6}$$

$$\frac{d^2 B}{ds^2} - P^{(1)}\frac{dB}{ds} + P^{(2)} B = 0 \tag{4.7}$$

$$P^{(1)} = \frac{1}{c}\left(\cos\theta\frac{\partial c}{\partial x} + \sin\theta\frac{\partial c}{\partial y}\right) \tag{4.8}$$

$$P^{(2)} = \frac{1}{c}\left(\sin^2\theta\frac{\partial^2 c}{\partial x^2} - 2\sin\theta\cos\theta\frac{\partial^2 c}{\partial x \partial y} + \cos^2\theta\frac{\partial^2 c}{\partial y^2}\right) \tag{4.9}$$

where D is water depth, θ is the angle between X axis and wave direction, S is the distance along wave ray and C is the phase velocity. Use numerical method to get

$$D_{n+1} = D_0 + \left(\frac{\partial D}{\partial x}\right)_n dx + \left(\frac{\partial D}{\partial y}\right)_n dy + \frac{1}{2}\left(\frac{\partial^2 D}{\partial x \partial y}\right) dxdx + \left(\frac{\partial^2 D}{\partial x \partial y}\right)_n dxdy + \frac{1}{2}\left(\frac{\partial^2 D}{\partial x \partial y}\right)_n dydy \quad (4.1)$$

$$P_{n+1} = [(4-2P_n^{(2)} \Delta s^2)/(2-P_n^{(1)} \Delta s^2)]\ B \ -[(2+P_n^{(1)} \Delta s) / (2-P_n^{(1)} \Delta s)]\ B_{n-1} \quad (4.11)$$

The subscript "n" represents the value of the nth calculation, as shown in Fig. 4.1. where X axis is taken parallel to the shoreline. Developing these numerical calculations to get "THE WAVE CHARACTER COMPUTING PROGRAM" (Hou, 1980), the wave characters such as K_r, K_s, H , C_g and θ could be found out at any water depth h=D. Since $\theta = \frac{\pi}{2} - \alpha$ as shown in Fig. 41. then

$$(P_\ell)_b = \frac{1}{8} \rho g H_b^2 \ (c_g)_b \ \cos\theta_b \ \sin\theta_b \quad (4.12)$$

is the alongshore breaking wave energy. For the self wave energy it is obtained as $(P_\ell)_b = 2.25 \times 10^{10}$ $kgm^2/sec^2/m$-yr.

5. Relationship between shelf waves and littoral drift in the NW coast of Taiwan.

From the echo sounding data, the littoral transport rate (I_ℓ) of the NW coast is calculated as 37.5 x $10^4 m^3$/yr.

I_ℓ and $(P_\ell)_b$ are in units of cgs system.

But for the Taiwan Strait where the climate is so steady that the alongshore breaking wave energy fluctuate slightly, the relationship between I_ℓ and $(P_\ell)_b$ could be expressed as

$$I_\ell = K(P_\ell)_b \quad (5.1)$$

Where K is constant and is equal to 0.14 for the north western coast of Taiwan.

The NW coast has the relation of $I_\ell = 0.14\ (P_\ell)_b$. This equation could be applied for the coast of similar oceanographic conditions and beach characteristics to estimate the littoral transport rate. Therefore, the harbor planning and shore protection could be based on.

The relationship between I_ℓ and $(P_\ell)_b$ is not exact linearly proportional to each other, this is proved by Eq(5.1) which is originally prepared by Komar and Inman (1970) there is a upper limit K = 0.77. Adding the data of the author, reanalyzing the total data by the least square method to get a regression line which is expressed as $I_\ell = 0.154\ (P_\ell)^{1.0695}$ as shown in Fig. 5.1.

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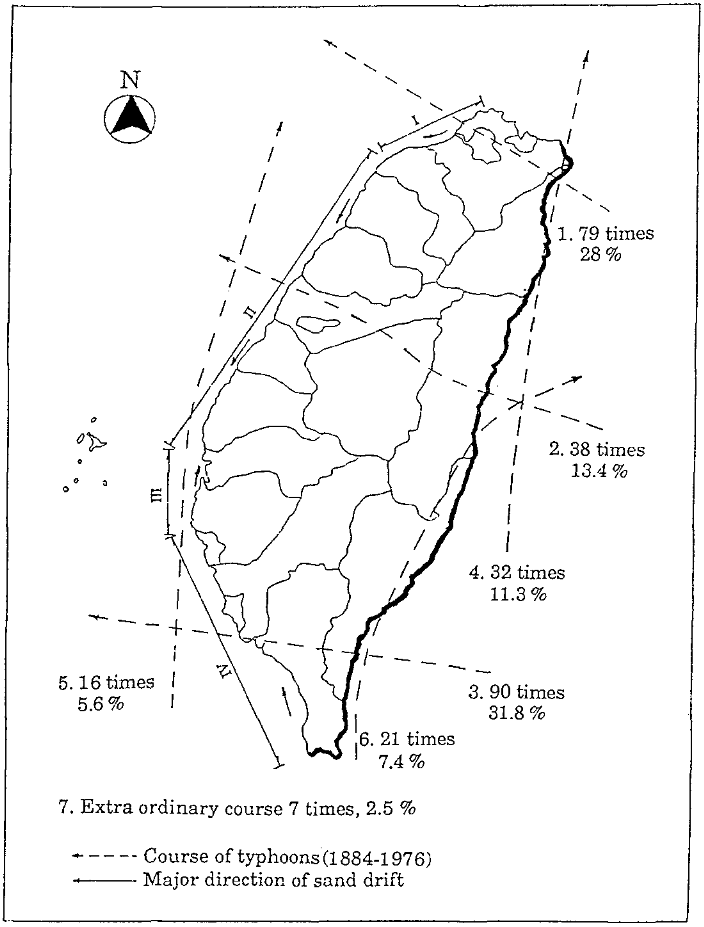


Fig.1 The sketch of the prevailing direction of littoral drift at Taiwan sandy coast

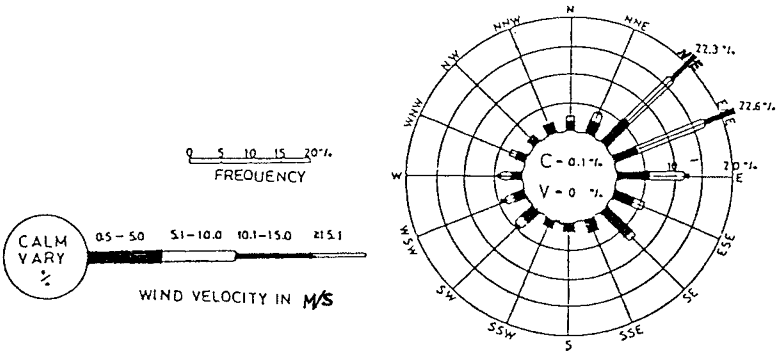


Fig.2.1 Wind Rose of the NW coast

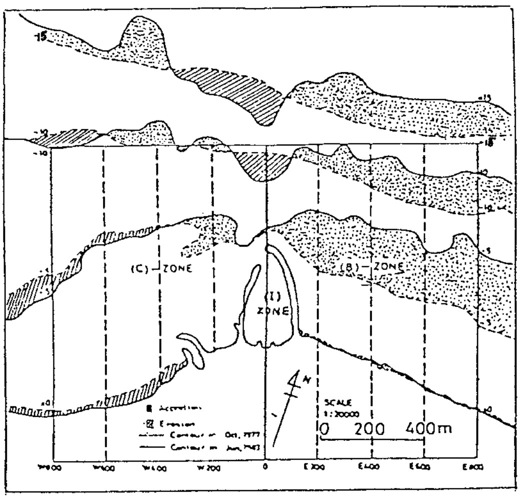


Fig 2.2 Accretion and Erosion of the
Profile near the Linkou

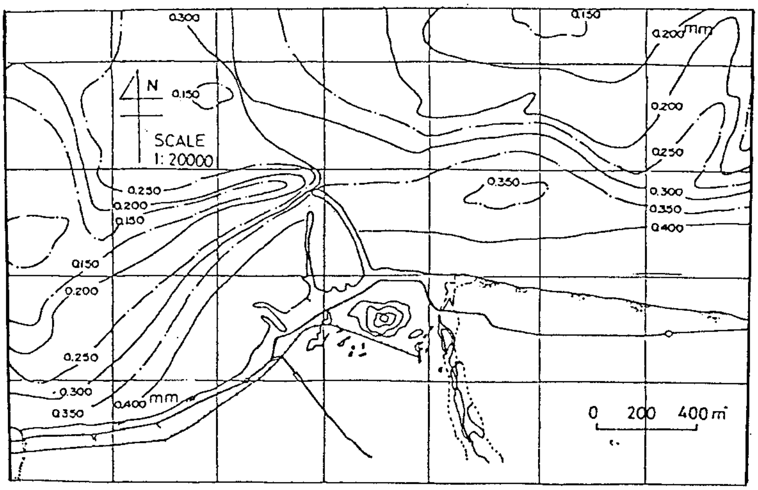


Fig.2.3 Sediment Particle d_{50} Distribution in the Nearshore Area of Linkou (mm)

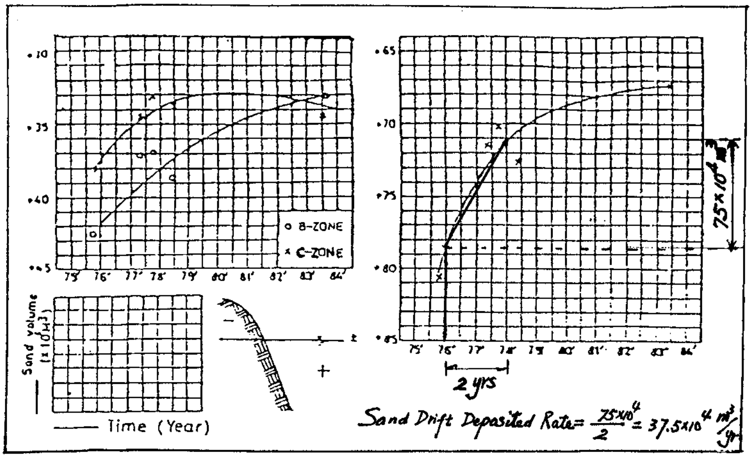


Fig.2.4 Sand Volume Change of Surveyed Zones B, C & B+C

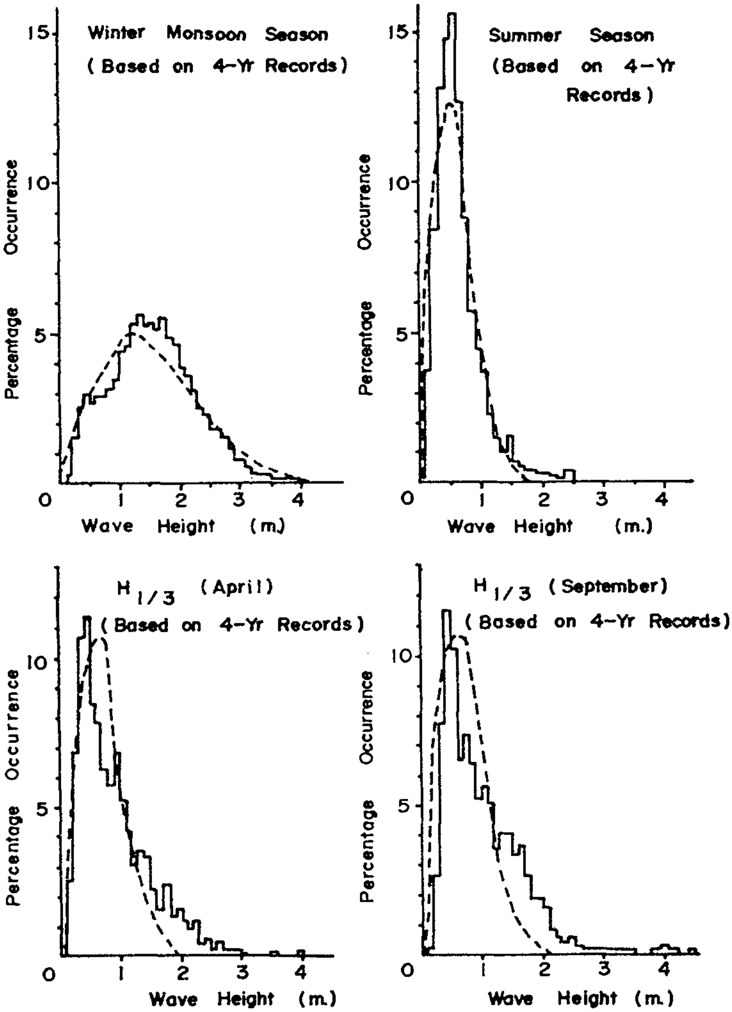
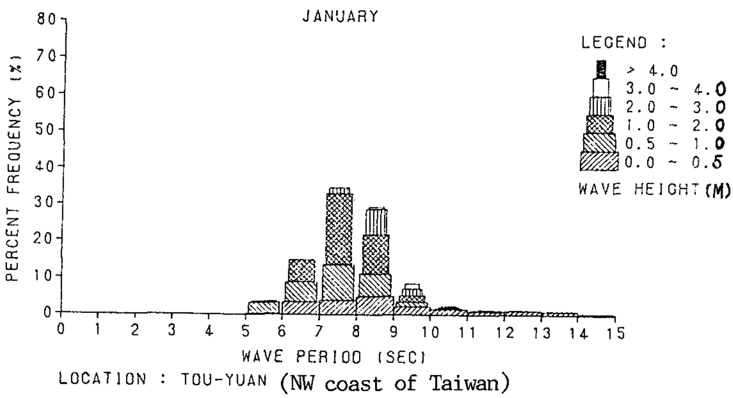


Fig.3.1 Distribution of Significant wave height
(Self Waves)



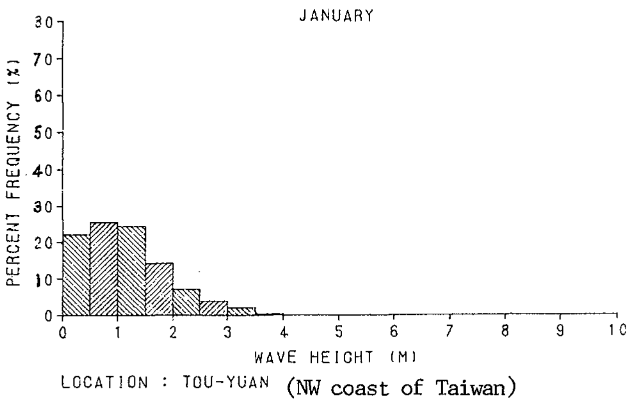
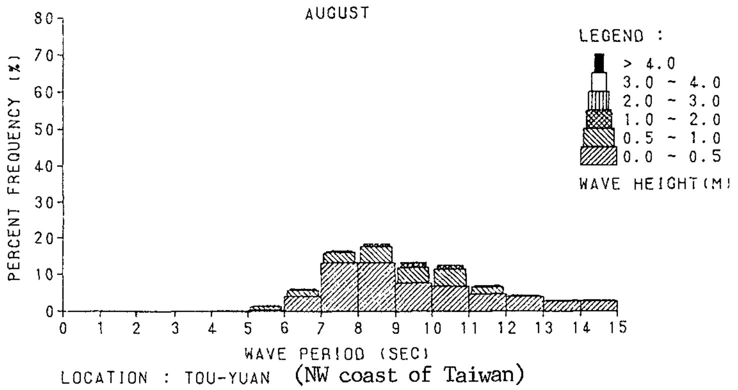


Fig.3.2. Relation of Wave period, Wave height vs Percent Frequency in NW coast of Taiwan (Winter)



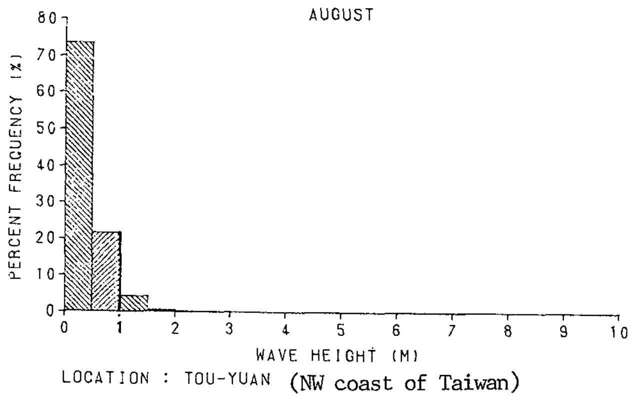
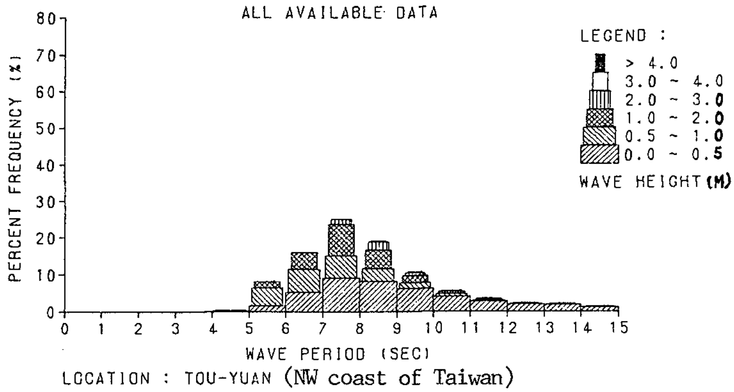


Fig.3.3 Relation of Wave period, wave height vs percent frequency in NW coast of Taiwan (Summer)



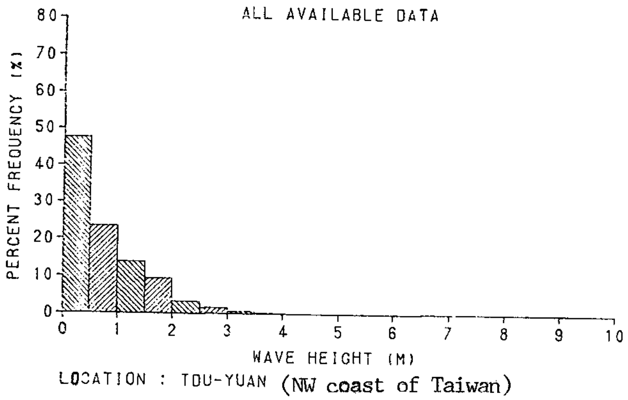
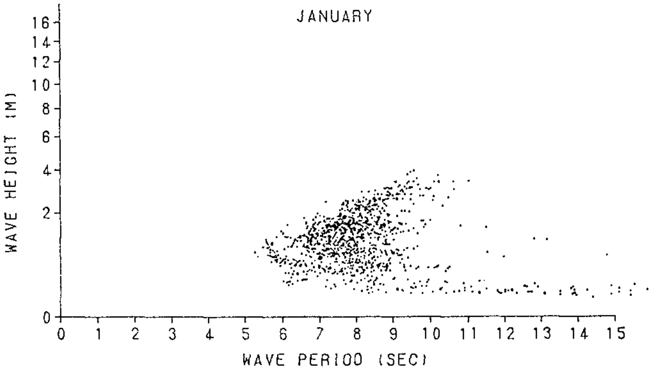
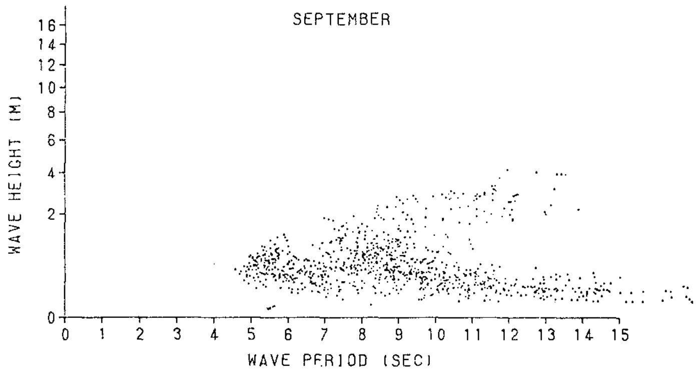


Fig.3.4 Relatiuon of wave period, wave height vs percent frequency in NW coast of Taiwan (the whole year)



LOCATION : TOU-YUAN (NW coast of Taiwan)



LOCATION : TOU-YUAN (NW coast of Taiwan)

Fig.3.5 Correlation between wave height and wave period in NW coast of Taiwan.

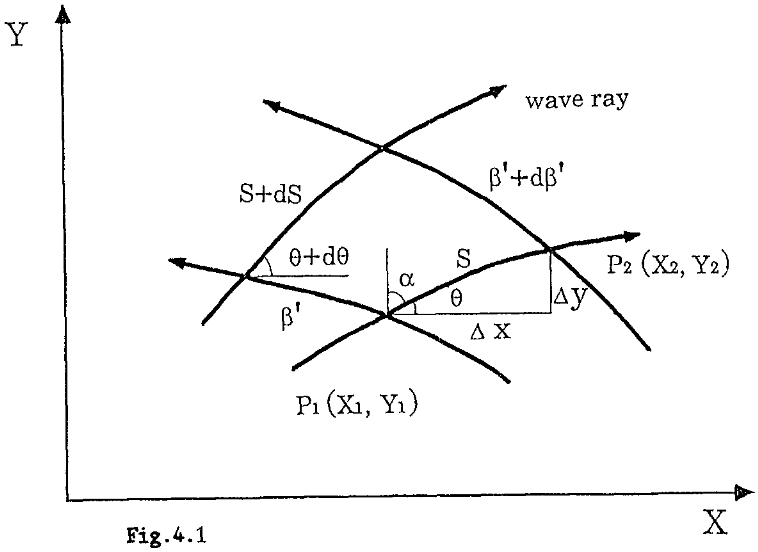


Fig.4.1

The diagram of the wave refraction

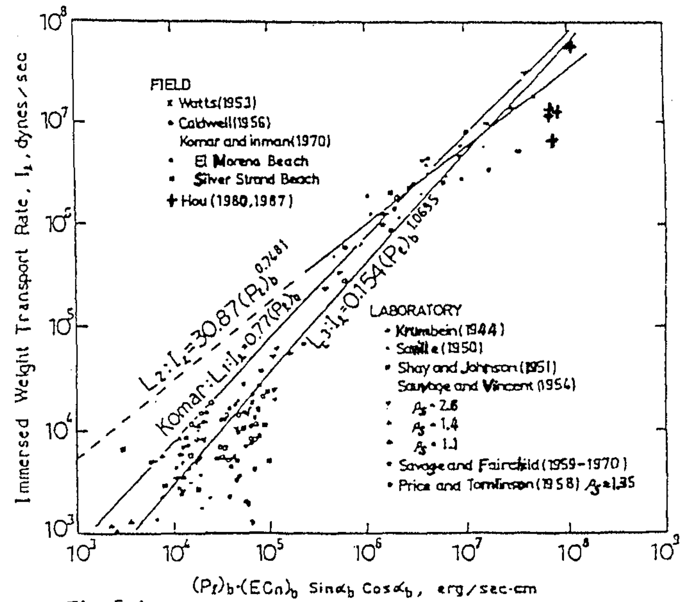


Fig.5.1

The relationship of the alongshore breaking wave energy and the immersed weight transport rate