特別寄稿

Coastal Engineering Problems in Construction of Harbour

(港灣建設에 있어서의 海岸工學問題)

本報告書는 第1回 臨海工業 團地造成에 關한 國際學術 發表大會에서 報告한 內容을 拔萃한 것임

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Introduction

In advance of the present International Symposium, the author has had an opportunity to make an inspection tour to some of the typical harbour areas in the Republic of Korea in July 1974. The tour was kindly arranged by the Industrial Sites and Water Resources Development Corporation. Through this tour, the author could get a general view on the present status of the coastal development in this country and on the various problems to be solved in order to promote the magnificient coastal projects which are now progressing under the great efforts of the Korean engineers.

In this paper the author wishes to introduce some results of investigations, most of which are reported in the proceedings of the Annual Conference on Coastal Engineering in Japan and other publications issued by the Japan Society of Civil Engineers during the last ten years.

The coast of the Republic of Korea is, as well-known, divided into three parts, namely 1) east coast, 2) south coast, and 3) west coast. Each coast seems to have remarkably different features from the other two in the geographical, geomorphological and oceanographical senses. The east coast, especially the northeastern part of Korean peninsula beyond Ulsan, has rather steep submaine slope, hence the waves must be the principal factor to be considered in the design and execution of harbour works, while the tidal range along this coast is not significant because of the small value less than 25cm. On the other hand, the west coast facing the Yellow Sea is affected by the tremendously large tidal range. But the wave condition along this coast is not serious as it is on the east coast, because the Yellow Sea is relatively shallow and also the main harbours there are sheltered by the numerous islands scattered along the west coast and promontories. Finally, the south coast is characterized by the intermediate features between the east and west coasts. That is to say, the tidal range is between 3.0m and 0.5m depending upon the location, and the principal harbours are located at the places sheltered by islands and promo ntories from rough sea. The Korean Channel between the southern coast of Korea and the Kyushu Island in Japan has rather shallow depth and narrow width, but the oceanic current there is relatively fast as 2 to 4 knots. From the geographical point of view, the easternpart of the south coast is quite similar to Yamaguchi area in Japan, while the remainder is similar to Fukuoka na

Nagasaki areas in Japan.

Considering the typical, and characterized situations of the coasts in this country, the author will pick up some topics which are matched respectively to each coast from the coastal engineering points of view.

Wave Characteristics in Shallow water

Wave Measurement and Data Treatment System

In order to determine the design waves for harbour facilities, especially for breakwaters, the wave measurement must be the primarily step and should be continued for several years, at least for three years. The instrumentation techniques for wave measurement have been improved greatly during the last ten years, hence the success rate of instrument operation has reached to almost 100% The next step is to establish the data treatment system in order to speed up the analysis of data with adequate

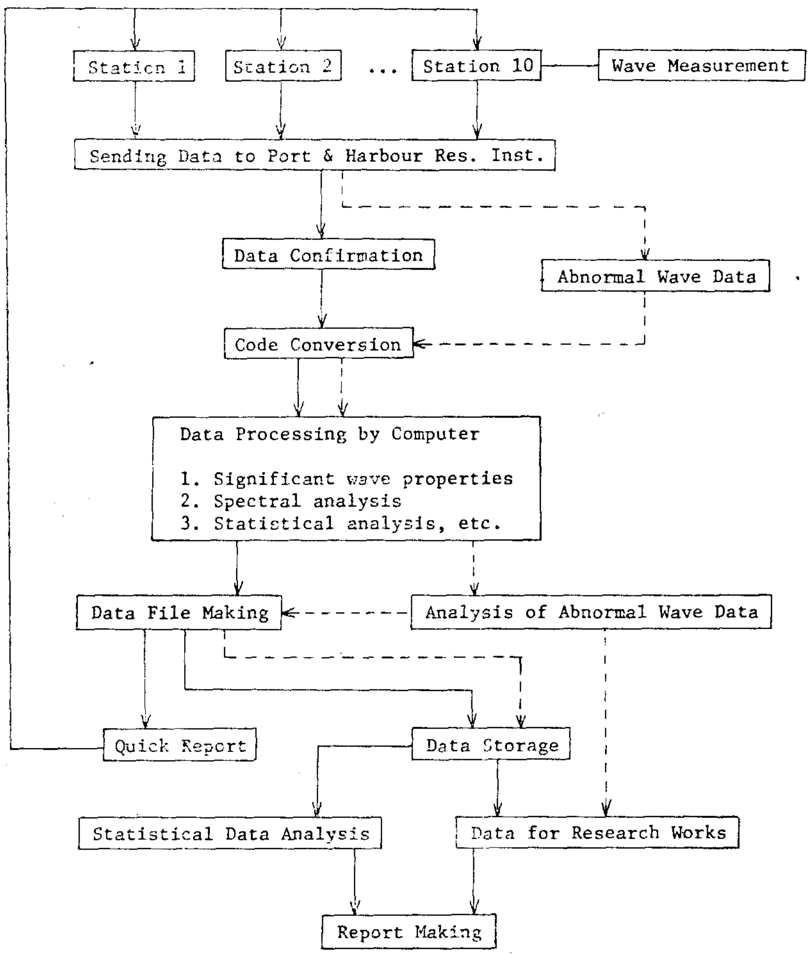
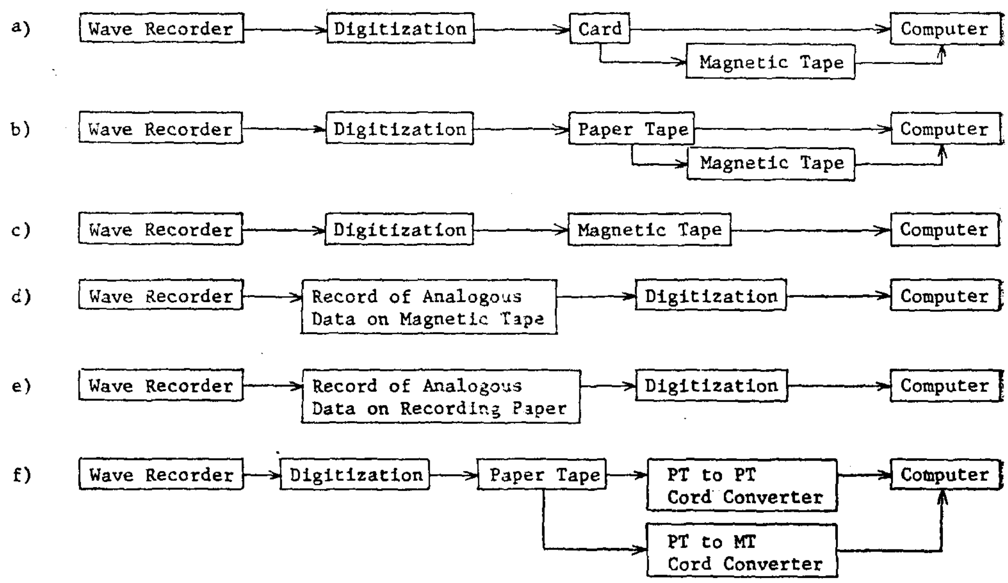


Fig. 1. Wave data processing system of Port & Harbour Research Institute, Ministry of Transport, Japan.



Figi 2. Wawe data processing system.(After Muraki)

accuracy for the practical purposes. It has been urgently discussed by scientists and engineers in the world on the virious occasions such as International Conferences on Coastal Engineering to make the standardized form of wave data treatment for many years, but the standardization has not yet been achieved. Reflecting the above situation, governmental agencies in Japan have established their own systems independently, among which the system applied by the Harbour Bureau, Ministry of Transport, seems to be therepresentative one in Japan.

The system is shown in Fig. 1. The ten measuring stations were selected from the numerous ones distributed along the Japanese Islands, and the data taken at each station by using magnetic tapes are sent to the Port and Harbour Research Institute, Ministry of Transport, for the statistical analysis. The results of the analysis are sent back to each wave station, and the data are stored there for the future higher order analysis, such as the spectral analysis of waves. There are various data treat ment systems, which are presently available, as shown in Fig. 2.

Statiscal Characteristics of Shallow Water Waves

It is well-known that the significant wave defined by Sverdrud and Munk(1947) is commonly used to express the complicated sea states. According to the theory of Cartwright and Longuet-Higgins (1956) which is based on the statistical theory, the relationships among the various statistical values of wave height such as $H_{1/10}$, $H_{1/3}$, H_{av} are expressed as functions of spectral band widthε. When ε is very small(this conditionis normally applicable to the actual sea waves), the distribution of wave height is expressed by the Rayleigh distribution curve as it is initially introduced by Longuet-Higgins (1952). Based on the assumption of the Rayleigh distribution of wave height, the following relationships are given:

$$\left.\begin{aligned} &H_{1/3}/H_{av}=1.60, \qquad H_{1/10}/H_{av}=1.27 \\ &H_{max}/H_{1/3}=1.07\sqrt{\log_{10}N} \quad \text{(for large value of } N) \end{aligned}\right\} \quad (1)$$

where N is the total number of waves.

The accurately recorded data of shallow water waves with rether large wave height have recently been accumulated at various locations in Japan. Analyzing the above data. the Japanese engineers have recognized that the ratween the characteristic wave heights cited in Eq. (1) decrease as the ratio between the significant wave height $H_{1/3}$ and the water depth h where the waves were measured increases. The above tendency is induced by the fact that the critical height of shallow water wave H_c is restricted by the water depth as well as the wave period. That is to say the waves larger than the critical one are cut out from the distribution of wave height, hence the wave height in shallow water is restricted in narrower range in comparison with the waves in deep water.

From the view point stated above, Kuo (1972) proposes the following wave height distributionmodel:

$$P_b(H) = \begin{cases} \dfrac{P(H)}{\int_0^{H_b} P(H)dH} & H > H_b \\ 0 & H \geqq H_b \end{cases} \tag{2}$$

here $P(H) = (2H/H_r^2)\exp[-(H/H_r)^2]$, that is the Rayleigh distribution, and H_r is r.m.s. of wave height. This model is constructed by adjusting the original Rayleigh distribution in the rangeof $H < H_b$ to satisfy the condition of $\int_0^{H_b} P_b(H)dH = 1$ as shown in Fig. 3. Using the present model, Kuo calculated the various relationships among the statistical wave heights and the most probable maximum wave height H_{max} as shown in Figs. 4 and 5 respectively. According to the comparisons between the theoretical value and the field observation data, the above results seem to be consistant. Goda (1973) also proposes another model of wave height distribution in shallow water (Fig. 6).

From these discussions, the engineers may recognize the importance of wave observations in order to understand the shallow water characteristics and to determine the design wave conditions.

Energy Spectrum of Shallow Water Waves

The energy spectrum of ocean waves has been treated by many researchers. Phillips(1966) expresses the spectral form in its equilibrium range of ocean waves by the following equation:

$$\Phi = \alpha \vartheta^2 \sigma^{-5} \quad (\sigma_1 < \sigma < \sigma_2) \tag{3}$$

where ($\Phi(\sigma)$ is the spectral energy, ϑ s the acceleration of gravity, $\sigma = 2\pi/T$ is the angular frequenccy, T is the wave period, and $\alpha = 1.47 \times 10^{-2}$ is a nondimensional constant.

On the other hand, the spectral form in the equilibrium range of shallow water waves must be restricted by water depth. Based on both theoretical and experimental treatments, Ijma and Matsuo (1969) proposed the following equation:

$$\left.\begin{aligned} \Phi(\sigma) &= 0.81 \times 10^{-2} h^{\frac{5}{2}} \vartheta^{\frac{1}{2}} \cdot F\left[\left(\frac{\sigma^2 h}{\vartheta}\right)^{\frac{1}{2}}\right] \\ F\left[\left(\frac{\sigma^2 h}{\vartheta}\right)^{\frac{1}{2}}\right] &= \frac{\left(\tanh \dfrac{2\pi h}{L}\right)^2}{\left(\dfrac{2\pi h}{L}\right)^2 \left(\dfrac{\sigma^2 h}{\vartheta}\right)^{\frac{1}{2}}} \end{aligned}\right\} \tag{4}$$

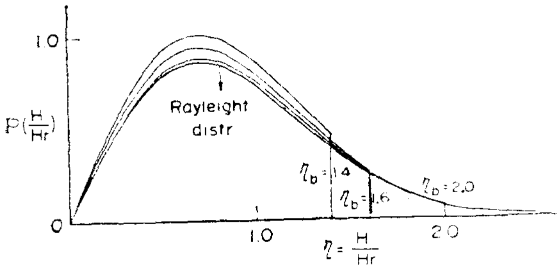


Fig. 3. A model of wave height distribution in shallow water proposed by Kuo & Kuo.

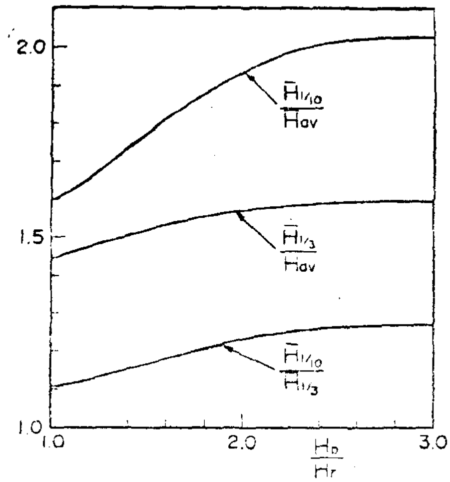


Fig. 4. Statistical wave height ration in shallow water. (AfterKuo & Kuo)

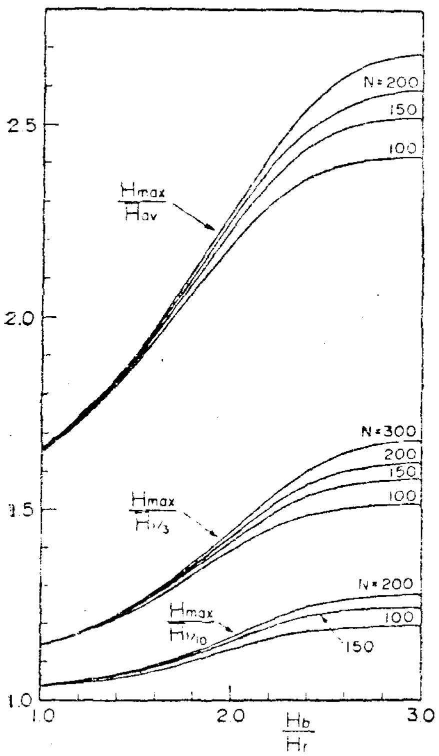


Fig. 5 Probable maximum wave height in shallow water. (After Kuo & Kuo)

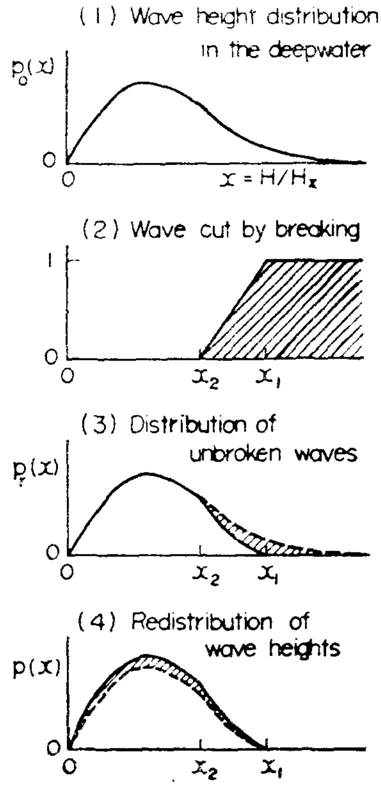


Fig. 6 A model of wave height distribution in shallow water proposed by Goda.

Figure 7 is the illustration to determine the energy spectrum of shallow water waves. The spectra of wind waves and swells in the ocean are assumed to be represented by MWO and ASO respectively in this figure. The curve given by Eq. (4) is drawn in Fig. 7 as MN, thence the spectra of wind waves and swells in the present shallow water region are expressde by MBCQ and ABCO respectively.

Based on the similar consideration, Kuo and Horikawa (1971) propose the following equation in place of Fq. (4):

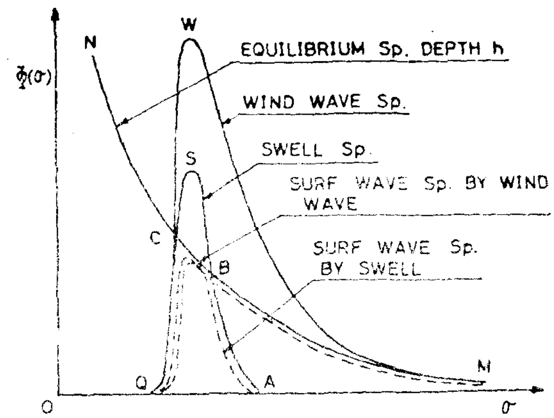


Fig. 7 Explanation sketch of wave spectra in shallow water. (After Ijima & Matsuo)

$$\Phi(\sigma) = \alpha g^2 \sigma^{-5} \tanh^4 kh \qquad (5)$$

They present also the relationship to determine the optimum frequency f_{op} $(1/2\pi)\sigma_{op}$ and the spectral energy density at f_{op} (Figs. 8 and 9), as well as the normalized spectrum of shallow water waves (Fig. 10), on the basis of the experimental data.

In the above treatment, are ignored the refraction effect and also the energy dissipation due toshear stress inside the turbulent boundary layer developed along the sea bottom. On the latter effect, Hasselmann (1968) calculates the dissipation of energy spectrum of incoming waves in formulating the energy balance equation, and compares with the feld data obtained at a particular site in the Gulf of Mixico, where the bottom slope is as gentle as 6.5×10^{-4} The result is shown in Fig. 11, where the spectrum at St. 1 is given. The agreement between thecomputed spectrum and the observed one is practically fairly consistant.

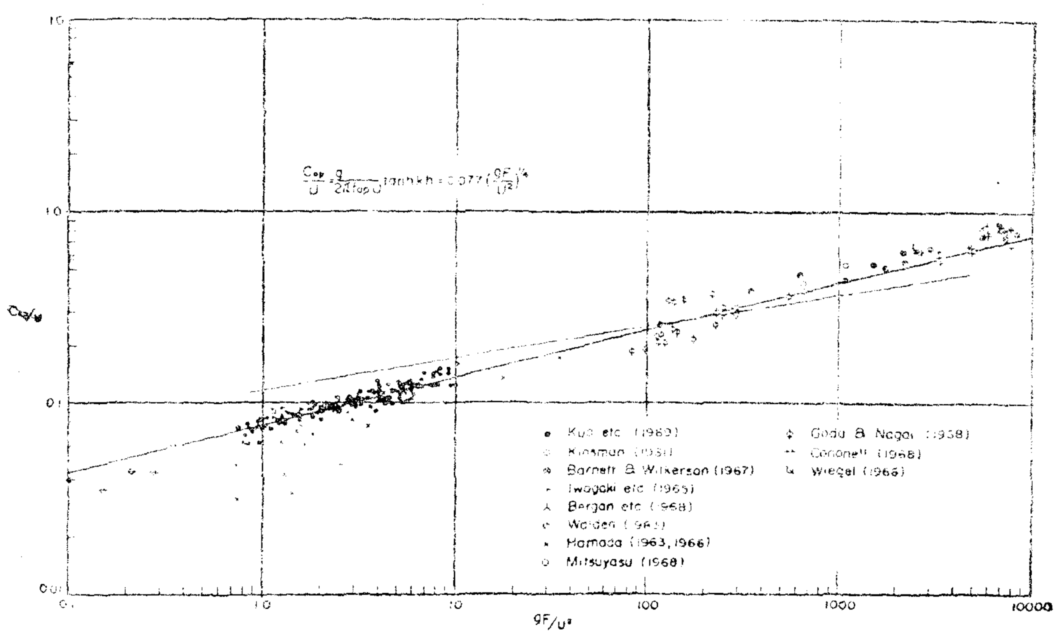


Fig. 8 Optimum frequency as a function of fetch in shallow water. (After Kuo & Horikawa)

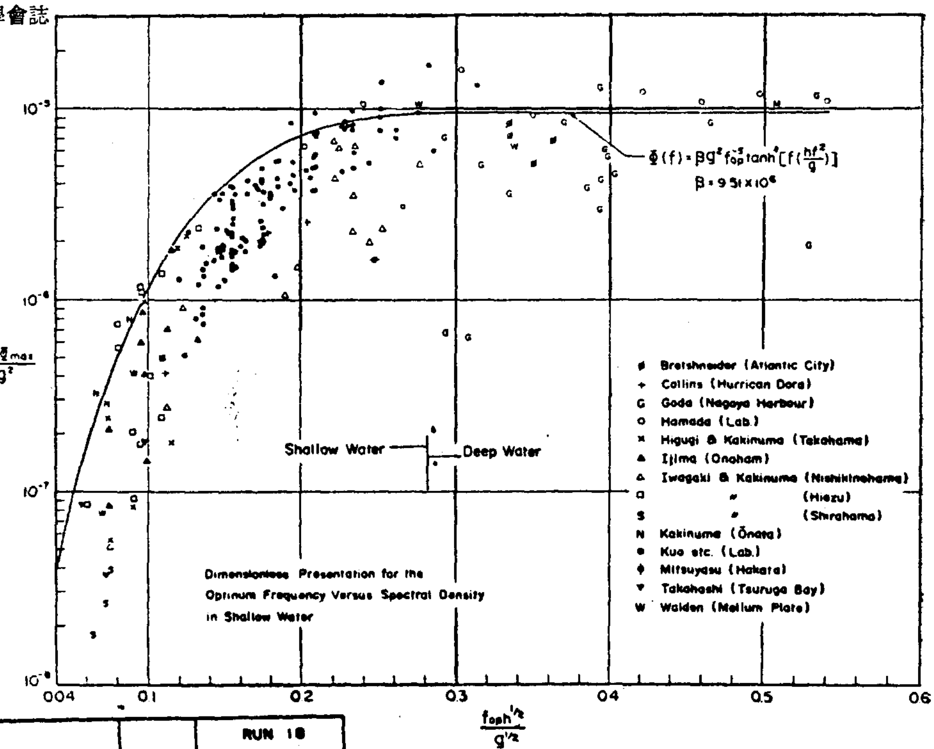


Fig. 9 Relationship of spectral peak versus optimum frequency in shallow water. (AfterKuo & Horikawa)

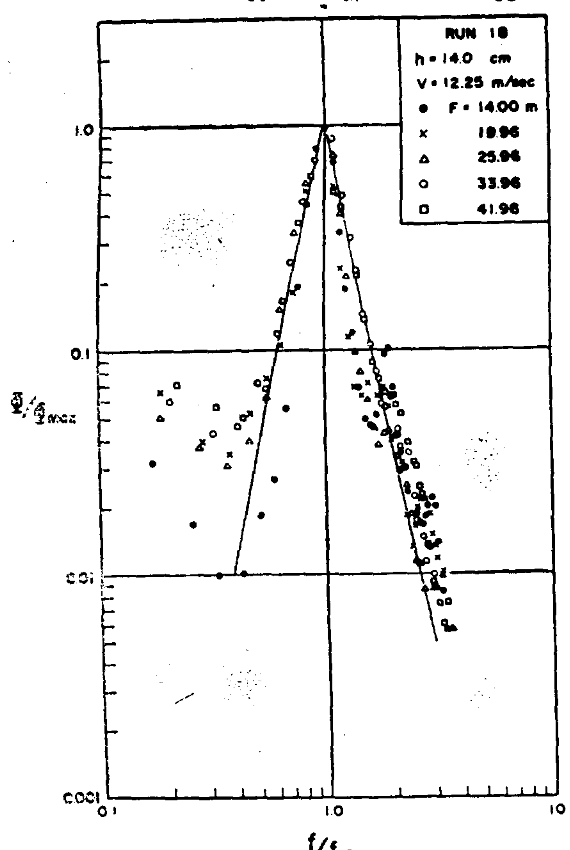


Fig. 10 Normalized wave spectra in shallow water. (After Kuo & Horikawa)

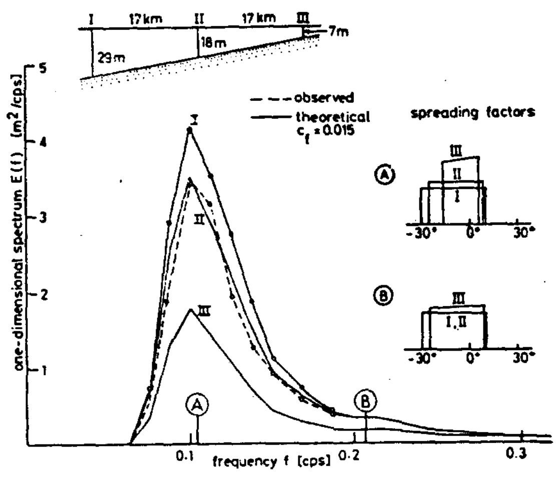
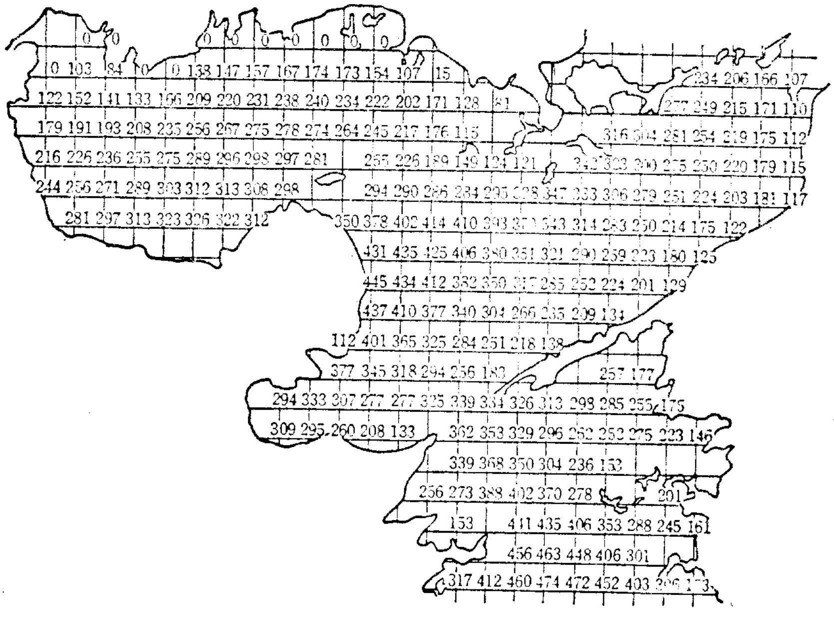
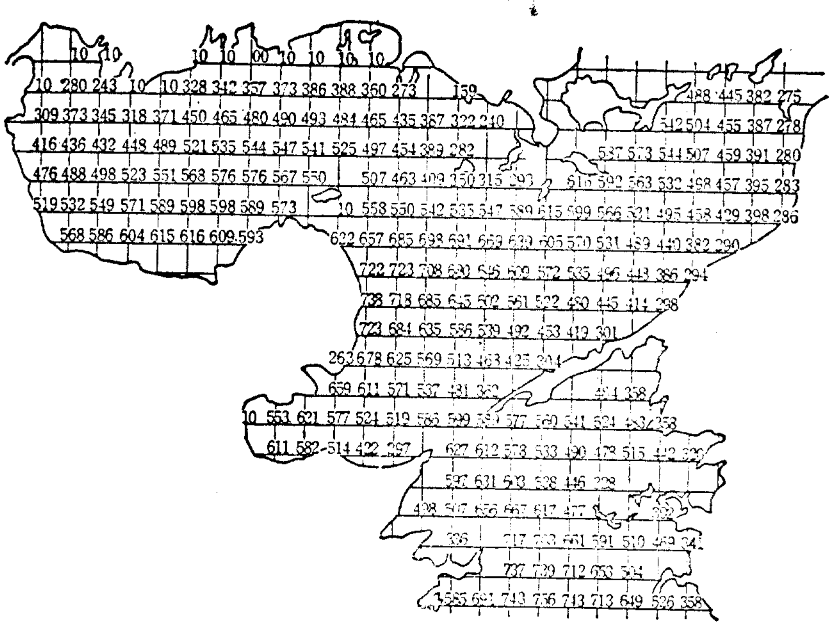


Fig. 11 Decay of a wave spectrum due to bottom fricti on Jor near-normal incidence on a constant-slope beach. (After Hasselmann)



(a) Distribution of significant waveheight im cm.



(b) Distribution of significant wave period in 10^{-2} sec.

Fig. 12 An example of predicted wave characteristics. (After Horikawa, Nishimura, et al.)

Wave Forecasting in Shallow Water

The diagrams presented by Bretschneider (1954) are commonly used for forecasting the wave characteristics in shallow water. But these diagrams are not applicable to the cases for wind waves generated by a typhoon, because the wind direction in the typhoon varies very quickly in a large scale. Therefore, Ijime (1968) has developed a method to compute the wind wave characteristics in a wind region of pythood by using an electronic computer. The method is based on several assumptions, the validity of which should be examined in more detail. The Ijima's method is basically to trace each ray of wave generated by wind at a certain point at a certain time, therefore the treatment after the computation being finished is rather complicative. In order to avoid the defect mentioned above, Horikawa and Nishimura (1971) has improved the computation method to get directly the wave height and wave period distributions at each step of time (Fig. 12).

Siltation Problems

Inception of Sediment Movement by Curret

Coastal sediment phenomena, such as beach erosionand siltution, are one of the most important and difficult problems to be solved in constructing harbour facilities along the coastal water front. In the Republic of Korea, the beach erosion problem does not draw any people's attention at present from the practical point of view, while the siltation problem seems to be keenly interested by engineers owing to the maintainance of the navigation channel.

Siltation is a result of sediment movement induced by current and/or wave motion. The representative current in the coastal region is undoubtedly the tidal current, which is the alternating current with normally a12-hour period. The period of tidal current is overwhelmingly long in comparison with that of wind generated waves, swell, and harbour surging; thus the tidal current is usually assumed to be a quasi steady flow.

The sediment movement due to steady flow has been studied theoretically and experimentally for a long term. Therefore voluminous data on this subject have been accumula ted, and these are powerful for understanding the various actual phenomena and for finding the direction of technological procedures to solve the siltation problems. Figure 13 is a well-known diagram presented by Hjulstrm (1935). From this figure the sediment state such as erosion, transportation and deposition can be determined for each combination ofof grain size and mean velocity of current. In the present cese the tidal current velocity at a certain stage can be used as the mean current velocity in this diagram. It should be mentioned that the grain size eroded by the weakest current is not the finest fraction but 0.3to0.5mm. The above fact can be explained by the followingreason. That is, when the grain is completely burried in the viscous sub-layer, greater velocities are needed to move such sediment particle.

In order to treat the sediment movement in more detail, the post studies on the threshold velocity should be refered. Fig urc 14 shows three representative curves giving the critical shear stress for the inception of sediment movement. These are curves given by Shields (1936), Kurihara (1948), and Iwagaki (1956). All of these are expressed in general bypthe following equation:

$$u_{*c}^2 \Big\backslash \left(\frac{\rho_s}{\rho_f}-1\right) g d = \phi\left(\frac{u_{*c} d}{\nu}\right) \qquad (6)$$

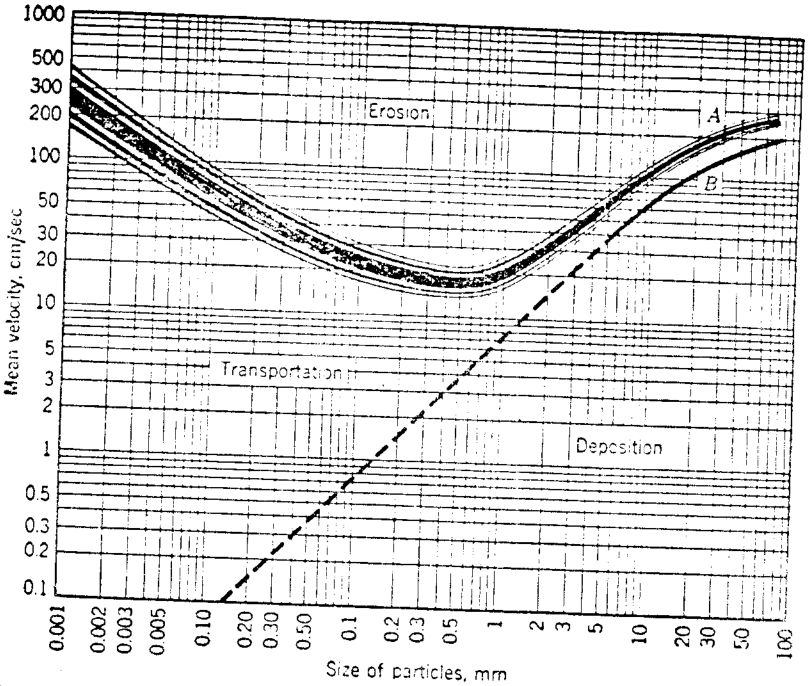


Fig. 13. Relationship between average current velocity and sediments showing velocities necessary for erosion, transportation, or deposition. (After Hjulstrm)

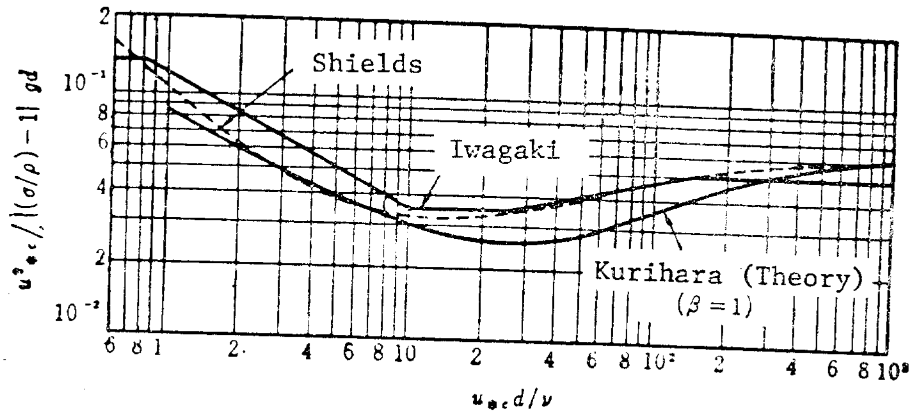


Fig. 14. Critical tractive forces.

where u_{*c} is the critical shear velocity, ρ_s and ρ_f are the density of sediment particle and density of fluid respectively, g is the acceleration of gravity, d is the diameter of grain size, and ν is the kinematic viscosity of fluid. The shear velocity can be evaluated by the equation of $u_* = \sqrt{gRI_e}$, where R is the hydraulic mean radius and I_e is the energy gradient. By using the above results, it might be possible to investigate the siltation problems by measuring the flow velocity in a hydraulic model with fixed bed.

Inception of Sediment Movement by Waves

Another important subject related to the siltation problems is to know the threshold condition of sediment movement due to wave action. The analysis on this criterion is also closely related with the elucidation of complicated mechanism of sand particle motion along the bottom. Numerous research works have been done in Japan, for example by Sato and Kishi (1952), Kurihara, Shinohara, et al. (1956), Inhihara and Swaragi (1960), Sato and Tanaka (1962), Noda and Iho (1964), Horikawa and Watanabe (1966), Noda (1966), and Sawaragi (1966). In addition to them Rance and Wallen (1968) have added valuable data of experimental works conducted by using an oscillatory flume. Here the auther will introduce the outline of these works.

The generalized form of the expressions for critical water depth obtained before 1962 is given by the following equation:

$$\frac{H_0}{L_0}=\alpha\left(\frac{d}{L_0}\right)^n \sinh\frac{2\pi h_i}{L}\left(\frac{H_0}{H}\right) \tag{7}$$

in which h_i is the critical water depth for sand movement, H_0 and L_0 are wave height anp length in deep water respectively, H and L are wave height and length at the critical water depth h_i respectively, and d is grain diameter. Both values of coefficient α and exponent n are different in way of expression by the numerous proposers as given in Table 1. Figure 15 shows the comparison of these

Table 1. Previous expressions of criterion for sedimen} movement.

	Sato & Kishi	Kurihara & Shinohara	Ishihara & Sawaragi	Sato &Tanaka	
n	1/2	1/2	1/4	1/3	
α	10.2	1.56~2.44	0.171	0.565	1.35
Patterns of mov.	General mov.	Initial mov.	Initial mov.	General mov.	Complete mov.

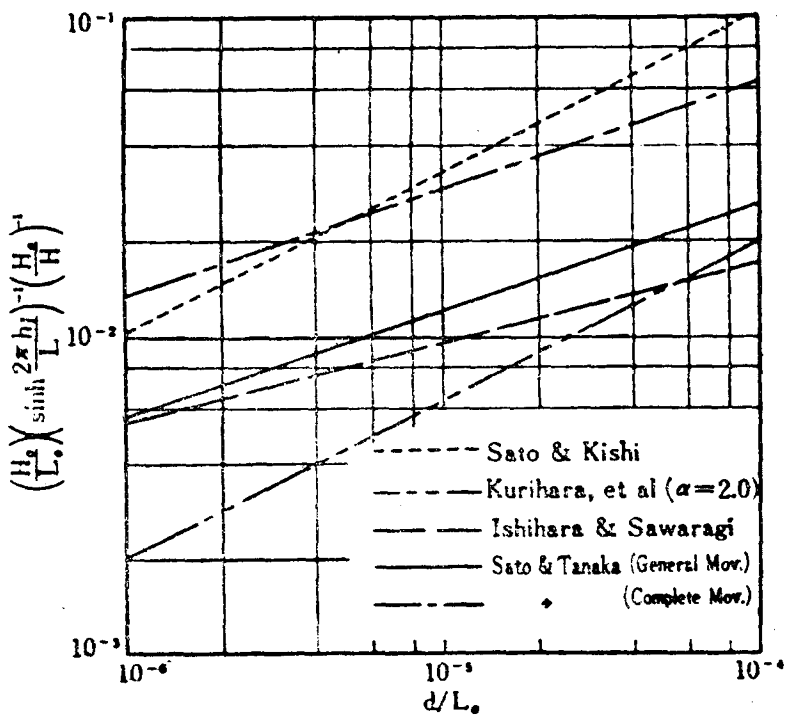


Fig. 15 Previous expressions of criterion for sediment movement.

various formulas. The possible reasons why the values of α and n are different in each formula will be as follows. The first reason will be found in the difference of definition on the criteria for the onset of sand movement. The second reason will be the fact that these investigations were conducted separately on the basis of numerous experimental data obtained under different conditions. Moreover the following two assumptions were taken into acaccount in the process of leasing the questioned criterion. That is, 1) the boundary layer is always laminar and 2) the frictional law for steady flow is still applicable evenin the case of of oscillatory boundary layer flow. The above assumptions, especially the latter, are quite questionable in the present treatment of oscillatory flow.

Owing to the above reasons Horikawa and Watanabe (1966) have tried to find out a generalized and more rigorous expression of the critical water depth for the onset of sand movement. That is to say, they have investigated the critical water depth by taking into consideration the bottom roughness and the boundary layer condition in the direction of the theoretical study on the frictional law for an oscillatory flow conducted by Kajiura (1964, 1965). Figures 16 and 17 show the results for the general movement under the laminar or smooth and turbulent condition, and the rough and turbulent condition respectively.

According to the result of their investigation the criterion of sediment movement due to wave action can be expressed by the functional relationship between $(\rho s/cf-1)\ gd\ \varphi/u_1^0$ and $u_0/\sigma d$ or $u_0\delta/\nu$ depending upon the conditions of bottom surface and of boundary layer, where $u_0=\frac{\pi H}{T}/\sinh\frac{2\pi h}{L}$ is the amplitude of horizontal velocity just outside the boundary layer due to progressive waves in shallow water, φ is the statical frictional angle of grainin water, $\sigma=2\pi/T$ is the angular frequency of wave, and $\delta=\sqrt{2\nu/\sigma}$ is a sort of boundary layer thickness. It is also concluded that the previous expressions for determining the critical water depth of sediment movement are all incomplete. The fact of L_0/δ should be introduced in the expression given by Eq. (7), that is to say, the Froude model law is always applicable to the present problem.

In order to investigate the applicability of of the present results to the sediment particles greater than fine sand, Horikawa and Watanabe (1969) took the data presented by Rance and Wallen (1968) and compared with the proposed curve for the condition of rough and turbulent flow. The agreement is surprisingly good as shown in Fig. 18. As for the applicability of proposed relation to silt, the author has not yet had any opportunity to check it, but believes that the relationship proposed for the condition of laminar or of smooth and turbulent flow might be applicable to this particular case.

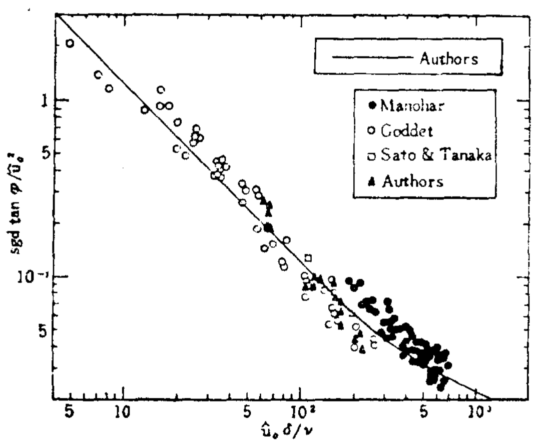


Fig. 19. Criterion for general movement-laminar and smooth turbulent-. (After Horikawa & Watanabe)

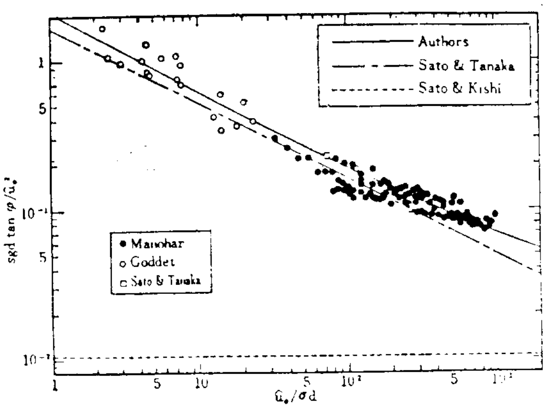


Fig. 17. Criterion for general movement-rough turbulent-. (After Horikawa & Watanable)

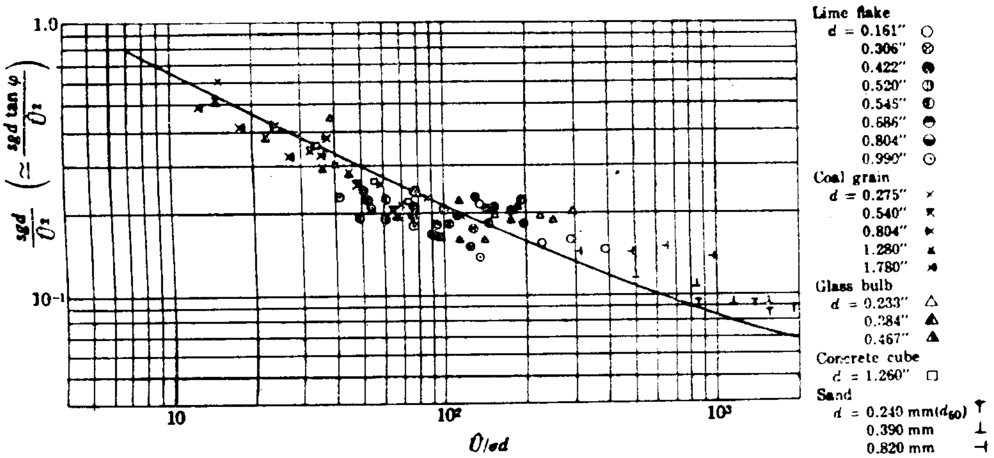


Fig. 18. Comparison between the Horikawa and Watanabe's criterion and the experimental data given by Rance and Warren. (After Horikawa & Watanabe)

Suspended Sediment Concentration

O'Connor (1970) presented a paper on the vertical distribution of suspended sediment concentration in a well mixed tidal estuary. The starting point for the analysis is the two dimensional longitudinal equation of motion, including the longitudinal salinity gradient term. Equations which representa steady state profile of sediment concentration are given.

It is shown that the result is quite similar to the expression obtained under the condition of uni-directional flow. An application of the theoretical equations to the Merry Estuary indicates reasonable agreement between observed and predicted sediment quantities for medium and coarse sand particles. While the agreement is shown to be worst for fine grain sediments. It is concluded that much better results can be obtained by using the non-steady one dimensional sediment distribution in discrete steps throughout the tidal cycle.

Hom-ma and Horikawa (1962) treated the problem to determine the vertical distribution of suspended sediment due to wave action. At that stage the eddy viscosity induced by oscillatory flow was very scare, hence they made a daring assumption on the characteristics of eddy viscosity and solved the fundamental equation ofsuspended sediment concentration. Comparing the theoretical one with the empirical data obtained both in field and in laboratory, they determined one empirical constant in a graphical form. Figures 19 (a) and (b) are the comparisons between the evaluated curves and the data, and show that the agreement between them is fairly good from the engineering point of view.

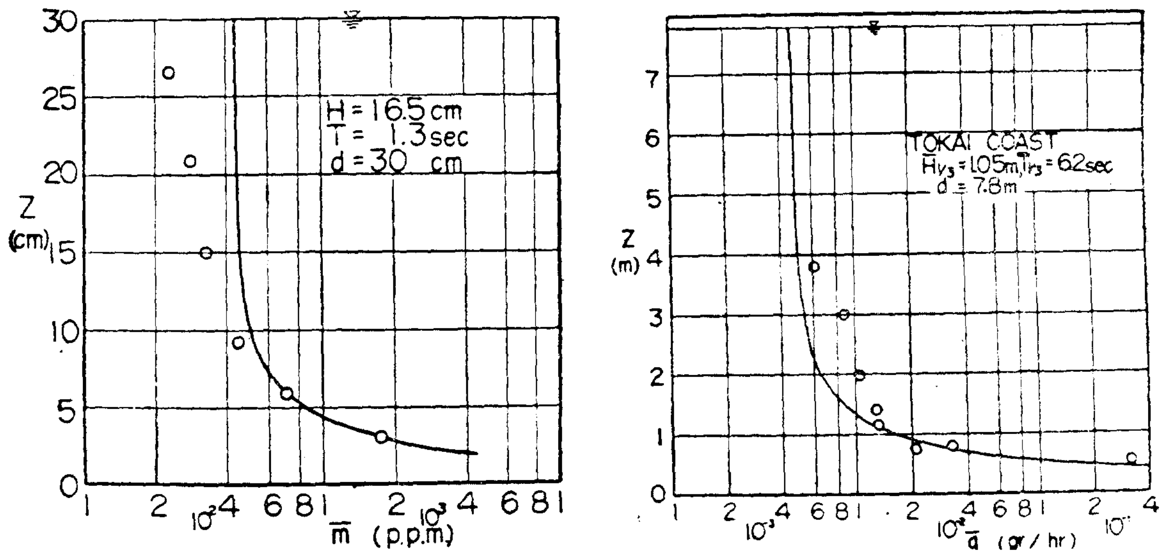
Transport Rate of Sediment

In order to solve thesiltation problems completely, it is urgently needed to evaluate the transport rate of sediment. But unfortunately at present any reliable formula on the sediment transport rate due to oscillatory flow has not yet been known.

Model Studies

Importance and Limitation of Model Studies

It is not necessary tosay that the actual phenomena in the coastal water is too complicative to be formulated in the analytical equations. Therefore, the hydraulic model is commonly used to solve the numerous practical problems and also to observe the actual state under the controlled conditions. In this case the dynamical similarity between prototypes and models should be hold in order to accomplish the purposes of model study. The Froude model law is normally applied to the various wave actions



(a) Laboratory data. (b) Field data.

Fig. 19 Vertical distributions of suspended sediment concentration (Comparison between analytical curve and measured data). (After Hom-ma & Horikawa)

such as wave transformation, wave forces, wave run-up, wave overtopping, etc., because the fluid viscosity has a minor effect on these wave movements. But in the case of sediment transport due to wave and current, the mechanism is not so simple to be described by the Froude model law as stated in the previous chapter. From that point of view, the appropriate model law for the sediment movement has not yet been known, hence the trial and error approach is still tak3n in the movable bed model study. Nevertheless such a model study is useful enough to have an insight into the phenomena in the qualitative sense.

On the other hand the numerical model studies havebeen conducted during the last more than ten years, since the the electronic computation techniques have been developed and used for the practical purposes. The first one of the numerical model tests in Japan was to hindcast the time history of storm surges generated by Typhoon No. 15 in 1959 at numerous stations in Ise Bay. At that time the main object of this study was to evaluate the efficiency of the then planned storm surge breakwaters on the reduction of water level in the besin sheltered by these breakwaters. Following that study, the function of tsunami brea kwaters on the damping of tsunami he ight was investigated by the method of numerical computation. Since then the importance of the numerical model study has been accepted very widely, and applied to the various problems such as to predict the typhoon generated wave chara cteristics, the temperature distribution of water induced by he ated water discharage, and the concen tration of pollutant in bays such as the Seto Inland Sea, Tokyo Bay, etc. Looking at these significant results, people is used to take thf impression that the numericaI model most be almighty. But this ih not true by the following reasons. In order to accomplish the compulational operations, the formulation should be done as the first step. In that case there are normally various unknown factors, hence some suitable assumptions should be made. At anyrate the computed results should be calibrated in comparison with the observed data. This sitcation is quite similar to the hydraulic model studies.

According to the author's opinion, the actual phenomena have not yet been fully formulated at present, hence the hydraulic model and the the numerical model have the same the weight at present. Therefore the engineer should consider which is the most suitable way for a particular purpose and select the adequate oue from the various view points.

Tidal Model Studies

The scale of tidel motion is very large in comparison with that of short period waves such as wind waves and swell, and the tidal Current is quite sensitiv ely affected by tooographical conditions. From these point of view, the distorted models have practically been used for the hydraulic model studies as shown in Table 2. All of the model studies listed in this table have conducted at various organi zations in Japan during the last 20 years.

The purposes of his model studies can be classified into the following groups: that is, 1) to investi gate the effect of civil engineering works(for example, reclamation works, breakwater construction, etc.) ontide and tidal current, 2) to find the suitable measures against siltation problems, 3) to know the amounthof sea water exchange between adjecent sea areas, 4) to evaluate the mixing and diffusion processes of pollut ion material in a particular boy, and 5) others. All of these phenomena mentioned above are too complicative to be simulated in a hydraulic model simultaneously. The refore, the research engineer should first of all determine the principal purpose of the present study, and then consider the similarity conditions based onthe equations governing the specified phenomena. The reader should investigate some appropriate references to find the detailed description on the ways how to determine the conditions of scale model.

It is certain that the hydraulic model is not the unique way to solve the practical problems. In some cases when the appropriate formulation is possible, the numerical model is rather powerful to grasp the general situation or the overall aspect of physical parameters in space and in time.

Model Studies by Using Movable Bed Materials

As stated in the previous chapter, the physical criterion for the inception of sediment movement due to current or wave action has been clarifirly well up to now, while the net transport rate of sediment induced by the alternating current or waves has not been yet formulated. The latter must be the most important reason why the model studies on sediment movement have run on a dead rock.

But in some particular cases, the model study by using movable bed materials can contribute very much to solve practical problems. As an example the author wishes to mention here the model study conducted by Noda (1966) in order to find out the preventive measures against the filling-up of the basin by drifting materials mainly in suspension. Noda used vinyl pellets as sediment meterialin model. The selection of bed materials is based on the following result:

$$\frac{w_{op}}{w_{om}}=\left(\frac{l^{4}}{l_{m}}\right) \tag{2}$$

Table 2. Tidal model studies conducted inJapan.(After Higuchi)

Location	Scale		Distortion	Name of Organization	Year
	Horizontal	Vertical			
Eastern part of Seto Inlaud Sea	100,000	1,000	100	Kobe Mar. Obs.	1930
Hiroshima Bay	500	250	2	Disaster Prevention Res. Inst., Kyoto U.	1958
Ariake Sea	40,000	250	160	Nagasaki Mar. Obs.	1959
Kanmon Str.	350	60	5.8	Port & Harbor Tech. Res. Inst.	1959
Sakai Str.	500	125	4	Disaster Prevention Res. Inst., Kyoto U.	1959
Nagoya H.	2,000	667	3	ditto	1961
Tsugaru Str.	50,000	500	100	Hakodate Mar. Obs.	1961
Nagoya H.	700	500	1.4	Disaster Prevention Res. Inst., Kyoto U.	1962
Ariake Sea	8,000	250	32	Agr. Dep., Kyushu U.	1962
Kanmon Str.	300	100	3	4th Port & Harbor Constr. Bur.	1963
Ise Bay	100,0	65	15.4	Agr. Eng. Res. Stn	1963
Tokyo Bay	500	100	5	Coast. Eog. Kab. & Earthq.Res.Inst.,U.Tokyr	1964
Ariake Sea	2,000	200	10	Disaste Prevention Res. Inst., Kyoto U.	1966
Nakanoumi	400	50	8	Nakanoumi Reclamation Bur.	1967
Kashima Port	500	63	8	Disaster Prevention Res. Inst., Kyoto U.	1968
Tokyo Bay	2,000	100	20	Nat. Resources Res. Inst.	1968
Mizushima Sea	2,000	160	12.5	Disaster Prevention Res. Inst., Kyoto U.	1968
Nagasaki	1,000	50	20	Agr. Eng. Res. Stn.	1970
Matsukawa-ura	600	50	12	Disaster Prevention Res. Inst., Kyoto U.	1970
Okayama Bay	1,000	100	10	Nat. Res. Inst., Pollution & Resources	1970
Mikawa Bay	1,500	100	15	ditto	1970
Seto Inland Sea	100,000	1,000	100	Disaster Prevention Res. Inst., Kyoto U.	1971
Kurushima Str.	300	250	1.2	Port & Harbor Tech. Res. Inst.	1971
Tokyo Bay	2,000	100	20	ditto	1971
Osaka Bay	2,000	100	20	ditto	1971
Shibushi Bay	1,500	150	10	Nat. Res. Inst., Pollution & Resources	1972
Tokyo Bay	2,000	200	10	ditto	1972
Mikawa Bay	2'000	160	12.5	Disaster Prevention Res. Inst.,	1972
Matsuyama Dist.	1,000	200	5	Cent. Res. Inst., Electric Indnstry	1972
Nakanoumi	300	10	30	Agr. Dep., Kyoto U.	1972
Seto Inland Sea	2,000	160	12.5	Chubu Indust. Sci.s& Tech. Lab.	1973
Ise Bay	2,000	160	12.5	5th Port & Harbor	1974
Seto Inland Sea	50,000	500	100	Disaster Prevention under Res. Inst., Kyoto U. constr.	

where w_0 is the setting velocity of bed material, l is the linear scale, and subscriptions of p and m indicate prototype and model respectively. The above relationship should be investigated more critically because of the various assnmptions madein the treatment, but the result of laboratory experiment was quite satisfactory from the practical purposes.

Environmental Considerations in Coastal Zone Management

The industrialization of coastal zone area seems to beone of the national targets in the Republic of Korea from the economical point of view. In order to accomplish the present and future projects with great ssuccess, the people in this country have better to investigate carefully the achievements or/and results produced by the Japanese people. As you know, the economical development with tremendous rate has been achieved mainlydue to the industrialization of coastal areas. The line of economical policy was unbelievably successful, but on theother hand the various aspects of pollution problems have appeared and drawn the people's great and deep attenton. Reflecting the social needs, the Japanese Gover nment has established the numerous laws to prevent the further pollution. Therefore the private industries should pay some amount of fund in order to reduce the amount of pollutions in waste disposal. According tothe published data, the amount of investment thrown into equipping the suitable facilities for preventing the future pollution was about 1.7% of the total expenditure for the production facilities in 1965, the rate increased to 4.5% in 1970 and may reach to about 7.4% in 1975. Even though such a big amount of money has been spent for pollution control, it may be practically impossible to recover the natural sea state at present to the pleasant and acceptable environmental condition. The author hopes strongly that the people in this country dont repeat the same mistake as it was done in Japan.

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