CHAPTER 85

Effect on Roughness to Irregular Wave Run-up

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ABSTRACT

A study of the irregular wave runup and rundown phenomenon on rough impermeable slope is conducted in order to investigate the effects of various surface roughness to the wave runup-rundown activities based on various kind of dyke and incident wave conditions. The roughness of dyke surface was defined as f_r which is functions of shape of the slender rectangular obstacles and its displacement distance. Results shows that the correlation between the relative significant runup height (R_{us}/H_s) and the incident wave steepness (H_s/L) have the same tendency either in regular or in irregular waves. The relative runup height has its maximum value when the dyke slope ($\cot\theta$) near 2. Next, the runup characteristics in regular wave was agree well with the Rayleigh distribution but it is a little bit smaller than that the Rayleigh's in irregular wave. Besides, the strong correlation between the wave runup and the surf similarity parameter ξ was found. The decrease of the relative run-up height with the increase of the surface roughness was got also. It may be useful to applied into the design work of the seawall.

INTRODUCTION

Wave run-up on coastal structures such as seawalls, dykes and so forth, is an important factor in the design of the height of the structures; therefore, many studies on the wave runup phenomenon and its characteristics have been carried out. However, the studies of the effect of roughness on the dyke to the run-up height are still scarce to find. Therefore, a study of the irregular wave run-up and run-down phenomenon on rough impermeable slope was conducted here in order to investigate the effect of various surface roughness to the wave runup-rundown activities based on the different kind of the dyke and the incident wave conditions.

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ANALYTICAL CONSIDERATION

Based on the concept of control volume, the correlation among the incident wave energy, the reflected wave energy and the energy dissipation during the wave run-up and overtopping (as shown in Fig. 1) can be written as (Cross, 1972)

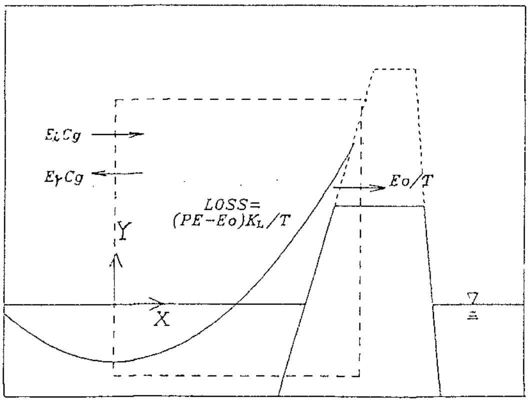

Fig.1 Definition sketch of runup and overtopping

$$E_i \cdot C_g - E_r \cdot C_g - \frac{E_o}{T} = \frac{PE - E_o}{T} \cdot K_l \tag{1}$$

where E_i: Incident wave energy density
E_r: Reflected wave energy density
C_g: Group velocity
E_o: Overtopping energy
PE: Potential energy of the entire runup wedge above SWL
K_l: Rundown energy loss coefficient
T : Wave period

By condition of no overtopping, the above equation can be simplified as

$$E_i \cdot C_g - E_r \cdot C_g = \frac{PE}{T} \cdot K_l \tag{2}$$

The potential energy PE can be computed (Juang, 1992) by the following equation with all notations was shown in Fig. 2.

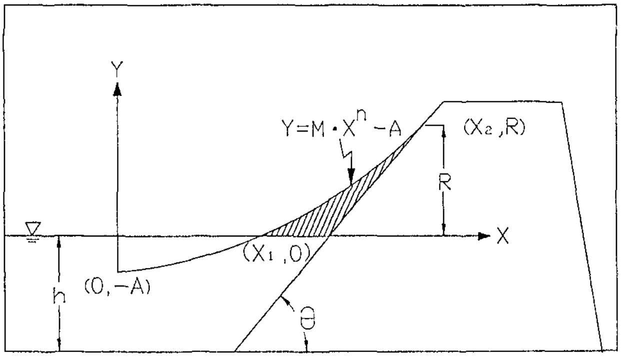

Fig.2 The shape of runup wedge

$$PE = \rho g \left\{ \int_{X_1}^{X_2} \frac{Y^2}{2} dx - \frac{R^3}{6\alpha} \right\}$$

$$= \frac{1}{2}\rho g \left\{ \frac{M^2}{2n+1}(X_2^{2n+1} - X_1^{2n+1}) - \frac{2 \cdot MA}{n+1}(X_2^{n+1} - X_1^{n+1}) + A^2(X_2 - X_1) - \frac{R^3}{3\alpha} \right\} \quad (3)$$

in which Y is the water surface elevation above the still water level at maximum runup. Its corresponding equation is

$$Y = M \cdot X^n - A \quad (4)$$

where X is the distance from the trough shoreward; A is the amplitude at the trough and M, n the coefficients that was function of surf parameter ξ ($=\tan\theta/\sqrt{H/L}$) as shown in Table 1.

By using the linear wave theory, the wave height in front of the inclining dyke becomes

Table 1 Values of M and n

$\cot\theta$	0.5	1.0	2.0	3.0
M	$54.228\xi^{-3.5}$	$5.993\xi^{-3.68}$	$1.748\xi^{-4.67}$	$0.437\xi^{-3.19}$
n	$1.0075\xi^{0.19}$	$0.608\xi^{0.59}$	$0.858\xi^{0.64}$	$0.873\xi^{0.59}$

$$H = H_i + H_r = H_i(1 + K_r) \tag{5}$$

where H_i: incident wave height
H_r: reflected wave height
K_r: reflection coefficient

Due to the wave energy was proportional to the wave height, therefore we can have

$$E_r = K_r^2 \cdot E_i \tag{6}$$

Substitute eq.(6) into eq.(2), the equation becomes

$$E_i(1 - K_r^2) \cdot C_g \cdot T = PE \cdot K_l$$

$$\text{or} \quad PE = \frac{1 - K_r^2}{K_l} \cdot E_i \cdot C_g \cdot T$$

DEFINITION OF ROUGHNESS COEFFICIENT

The roughness of the dike surface in this experiment study was made of small rectangle slender obstacles on the dyke as shown in Fig.3. The idea of that frame was come from the stream flow. Because the roughness coefficient at the bottom of the river was proportional to the diameter of the bed particles. Therefore, the roughness coefficient f_r in this study was defined by the following step.

(1) $f_r \propto D$; the higher the height of the slender obstacle, the rougher the roughness coefficient.
(2) $f_r \propto 1/W$; the wider the width of the slender obstacle, the smoother the roughness coefficient.
(3) $f_r \propto A_r = BD/D_m(B+W_m)$; the bigger the ratio of the effective cross section A_r to the maximum cross section, the rougher the roughness coefficient.

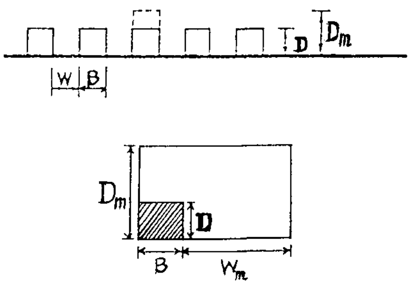

Fig.3 Definition diagram of the roughness coefficient

To view the whole situation that metioned above, we can defined the roughness coefficient as follow

$$f_r = \frac{BD^2}{WD_m(B + W_m)}$$

Various roughness coefficient (include f_r=0) with different ratio of D/B and W/B was shown in Table 2.

Table 2 Contrast table among D/B, W/B and f_r

D/B	0	0.25	0.25	0.25	0.5	1.0	1.0	1.0
W/B	0	4.5	3.0	1.5	1.5	4.5	3.0	1.5
f_r	0	0.0025	0.0038	0.0076	0.0303	0.0404	0.0606	0.1212

EXPERIMENT STUDY

A series of tests was carried out in a 100m long, 1.5m wide and 2m height wave flume. A random wave generator of servo-controlled electro-hydraulic system that was made by Danish Hydraulic Institute in Denmark is installed at one end. Artificial dyke model of various rough surface (include smooth) with four different kind of dyke slopes (cotθ = 0.5, 1, 2, 3) were installed at the other end where was 45m from the wave generator. The flume was divided into two sections. One equal 100 cm and the other 40 cm. The later (smaller) channel was used for measure the incident wave which will not to interfere by the reflected wave. All the experimental apparatus is shown in Fig.4.

Several wave gauge (ch.1 to 5) of capacitance type was used for measured the incident waves (Ch.1 to 4) and the run-up (Ch.5). The experiment was complete in conditions on fixed water depth (40cm) and incident wave period (1.2sec). The incident significant wave height are approximate to 3.5, 5.8, 6.8, 7.5, 8.0 and 8.8cm separately. The random waves used for tests were simulated to have Pierson-Moskowitz type spectra. Both of water surface variations of incident wave and run-up height were recorded simultaneously by an analog data recorder. The recorders were digitized by an A-D converter at a sampling interval of 0.025 sec. The measuring duration is about 100 sec.

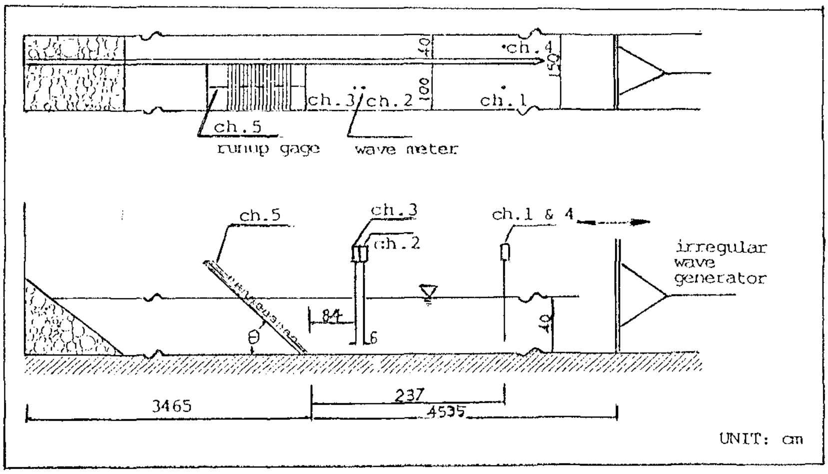

Fig.4 Layout of the test flume

For data analysis, at the begining, there have two ways to analyze the characteristics of incident and run-up waves. One is the statistics method to count out the significant wave. The other is the spectra analysis method to calculate the spectra energy then the significant wave height. Due to wave height and period are very important factors in wave structure interaction such as wave run-up. Therefore, the dimensionless distribution of relative wave height (H/H_m) to wave period (T/T_m) of the experimental waves was compared as shown in Fig.5. In the figure, it can be seen that the relative wave period (T/T_m) increases with the increase of wave height in the smaller waves ($H<1.3H_m$), but wave periods are distributed around $T/T_m=1.3$ in the wave field higher than arbitrary critical value ($H>1.3H_m$). Meanwhile, from the data shown in the figure, we have

$$H_{1/10} = 1.97\ H_m$$
$$H_{1/3} = 1.56\ H_m$$
$$T_{1/3} = T_{1/10} = T_{max} = 1.3\ T_m$$

It is identified from the above results that the joint distribution of wave height and period has a good agreement with the analyzed results of field data by Goda (1985). In other words, it can be stated that the simulated irregular waves used in model tests represent random ocean waves fairly well.

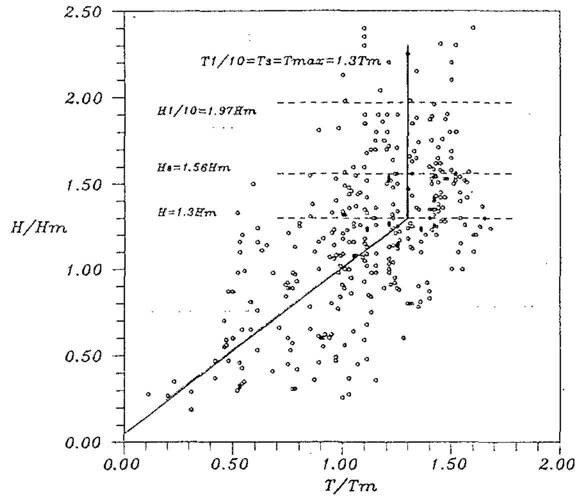

Fig.5 Joint distribution of wave height and wave period

In order to investigate the distribution status of the run-up waves of the irregular wave. The computational method of statistical significant wave height was used for counting the significant runup height (R_{us}) also. Part of the results (f_r=0 & f_r=0.1212) was shown in Fig.6 and Fig.7 respectively. From those figures, we can find the distribution of irregular wave runup heights (R_{us} to R_{um}) provides a good approximation to the Rayleigh distribution on the smooth surface dyke. But it will be overestimated when the dyke slope milder than 1 to 2 in rough surface (f_r=0.1212) test.

Secondly, all the experiment data which shows the relationship between the significant relative run-up and run-down height with the surf parameter was shown in Fig.8. In the figure, the envelope lines (1) and (2) indicate the extreme value of the relative run-up and run-down height respectively. Which was got from the experiment result by X_{ue} (1991) in condition of smooth dyke slope.

As to the effect of roughness to irregular wave runup, the relation diagram between the significant relative runup height and the surf similarity parameter in different kind of the surface roughness (f_r= 0~0.1212) was shown in Fig.9. From those figures, we can find that the effect of roughness to the relative runup height was certainly. If we sum up those correlation curves toge-

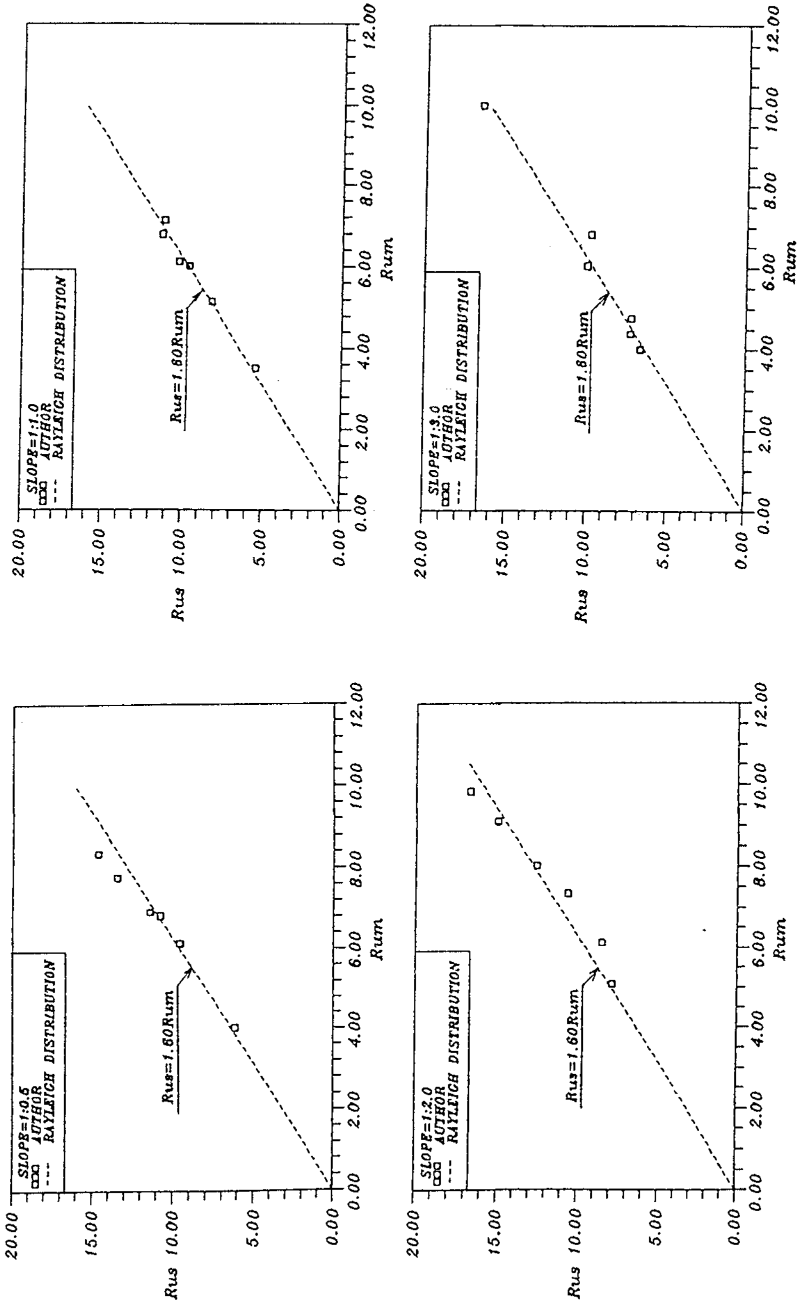

Fig.6 Relationship between significant runup height- and mean runup height in smooth dike

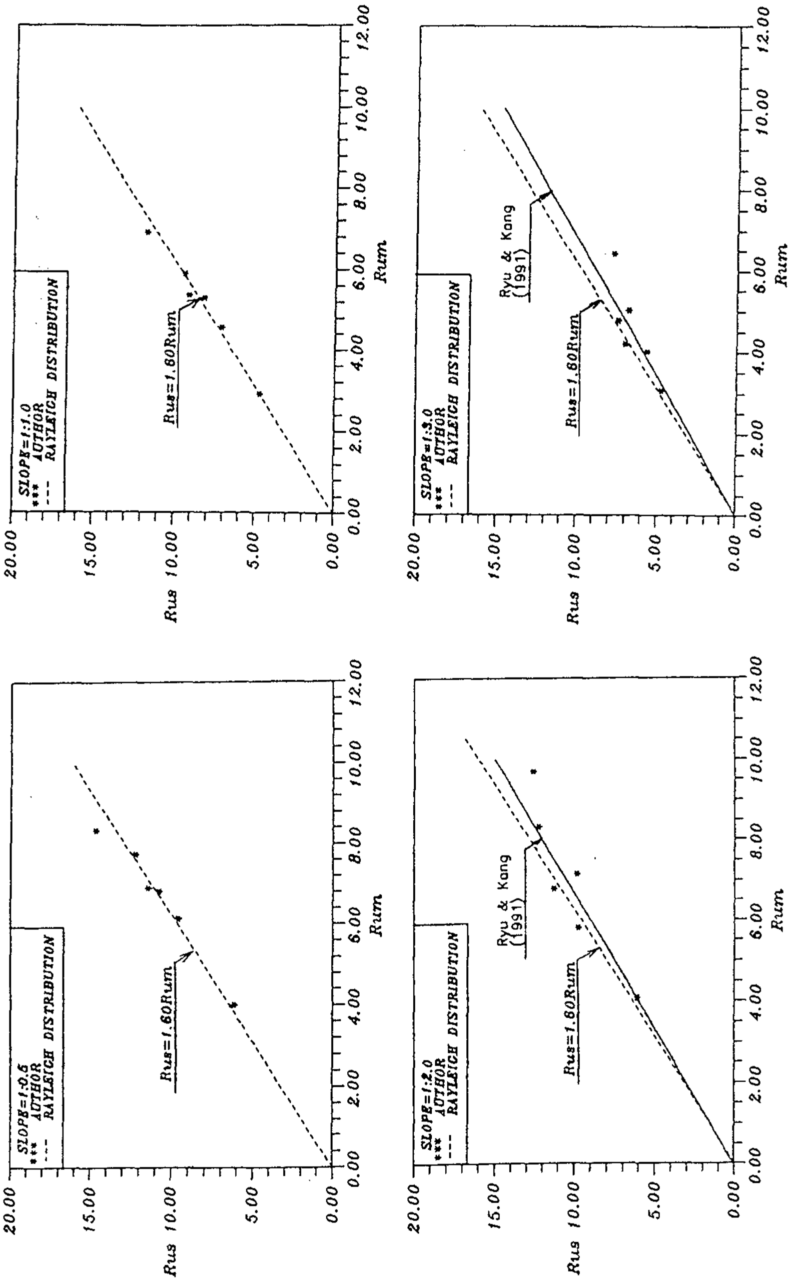

Fig.7 Relationship between significant runup height and mean runup height in rough dike

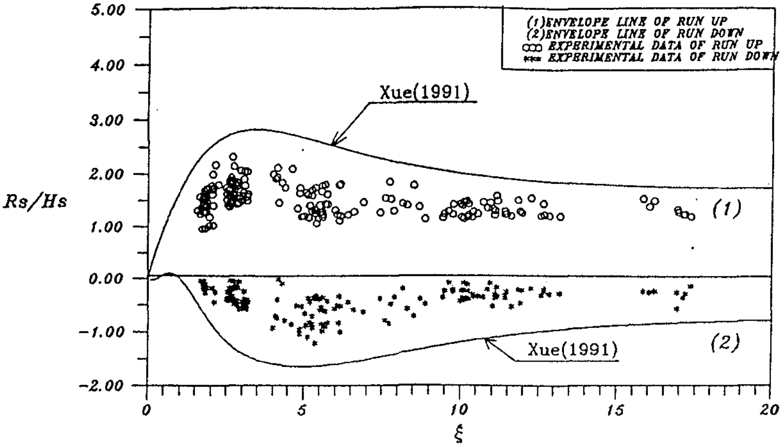

Fig.8 Relationship between run-up-down height and surf parameter

ther, we can find the rougher the surface of the dyke slope, the lower the relative runup height decreased as shown in Fig.10. When the roughness coefficient approach to 0.1212, the corretation curve between the relative runup and the surf parameter was very similar with those results which was presented by Ryu in 1990 in rubble mound experiment.

At last, the normalized relationship between the relative run-up and rundown height and the surf parameter was shown in Fig.11 and 12 respectively. The meaning of normalized stand for the ratio of relative run-up(down) height in rough dyke compared with those in smooth dyke. From the figures, we can see that when the surf parameter becomes bigger, that means the dyke slope approach to vertical, the influence of roughness to wave run-up-down height will vanished.

CONCLUSIONS

1. The distribution of the irregular wave runup heights provides a good approximation to the Rayleigh distribution on the smooth surface dyke. But it will be overestimated when the dyke slope milder than 1 to 2 in rough surface test.
2. The effect of roughness to the relative runup height was certainly and the rougher the surface of the dyke slope, the lower the relative runup height will decreased.
3. When the roughness coefficient approach to 0.1212, the relation

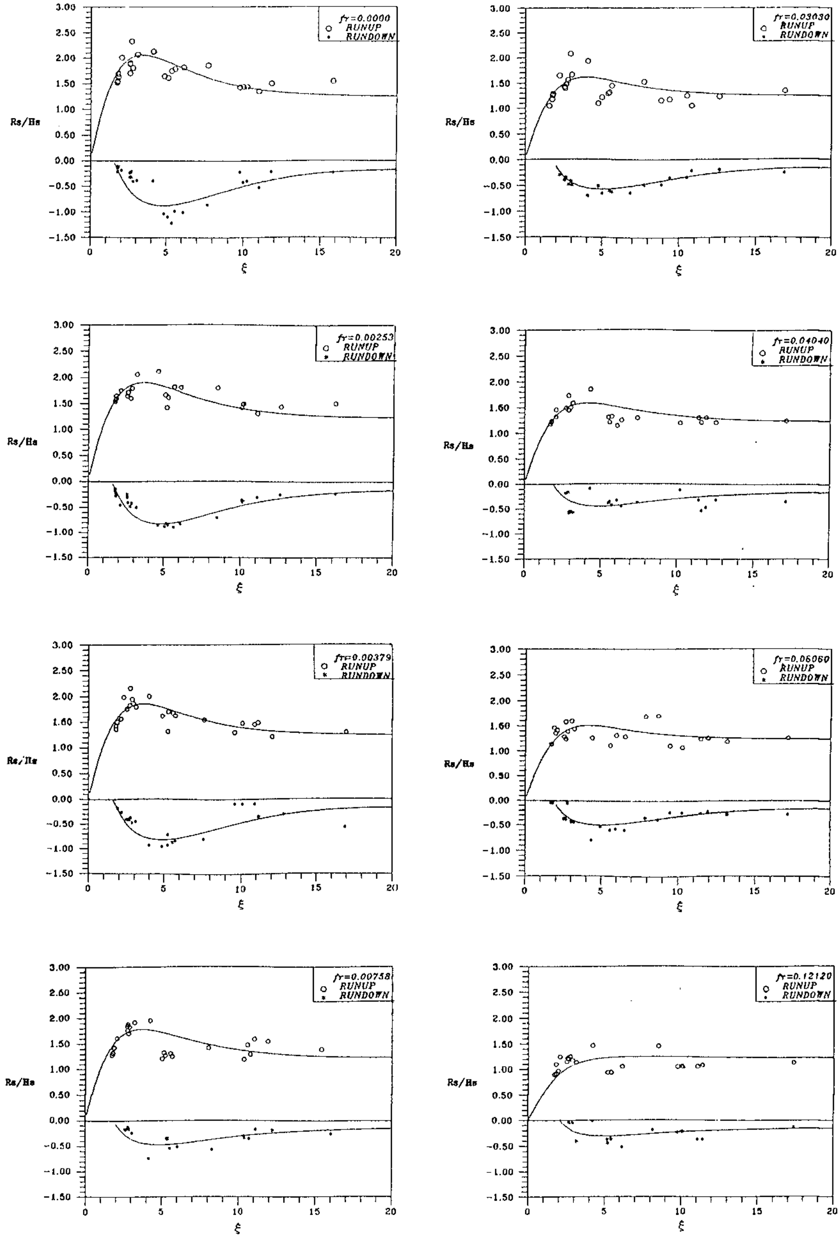

Fig.9 Relationship between significant relative runup height and the surf parameter

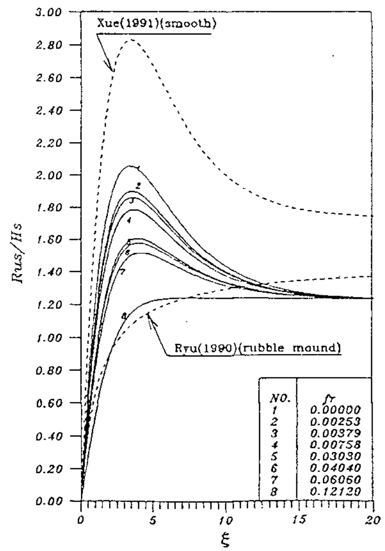

Fig.10 Comparison of relative runup in various rough surface

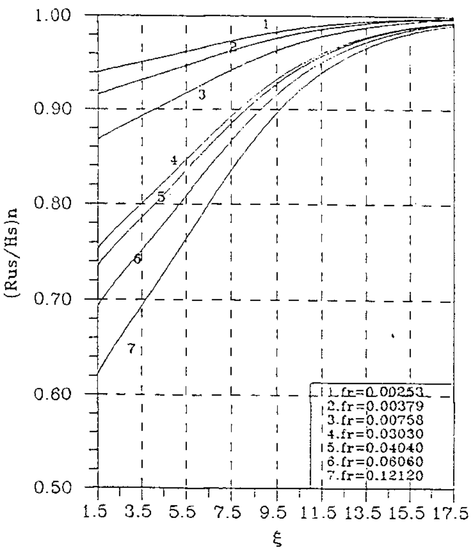

Fig.11 Normalized correlation of runup height to surf parameter

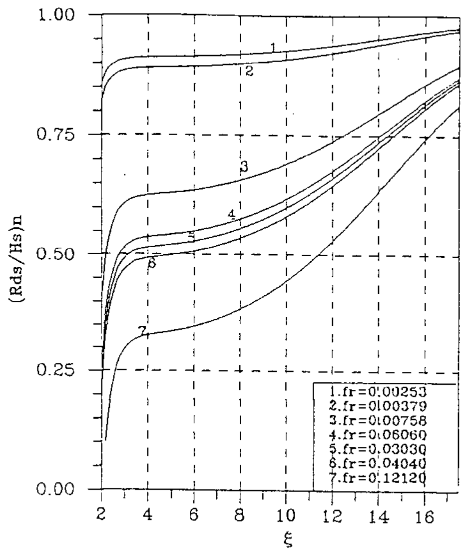

Fig.12 Normalized correlation of rundown height to surf parameter

curve between the relative runup height and the surf parameter was quite similar with those results in rubble mound experiment.

4. When the surf parameter becomes bigger, that's the dyke slope approach to vertical, the influence of roughness to wave run-up-down height will vanished.

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