CHAPTER 94

Effect on Wind Speed to Wave Run-up

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Abstract

In theoretical study, when the maximum run-up on seawall was happened, the shape of the run-up wedge is assumed to be a parabola with its vertex at the bottom of the first wave trough. The another assumptions are the conservation of mass and momentum. In model test, four kinds of dyke slope (1:0.5, 1:1, 1:2, 1:3)were choiced and the tests of the wind speed from 0 to 16 m/s accompany with a range of wave steepness were completed. The experimental data shows that the general form of the equations to developped was correct. Comparison of the theoretical estimations and the experimental data are coincident very well. Besides, the relation coefficient between the exponential value n of the parabolic runup shape with the surf parameter (ξ) was ranged in 0.19 to 0.65 in different kinds of dyke slope have been found also. At last, in general speaking, in spite of the strength of the wind speed, the relative run-up becomes the biggest when the dyke slope was 1:2.

Introduction

In case to determined the height of the sea wall,the height of the wave run-up is one of the most important factor. Parameters which will effect the run-up height

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was included not only the wave steepness, the relative depth before the toe of the coastal structure, but also the bottom slope. However, one of the most important parameter which always been neglected is the onshore strong wind speed. During the typhoon season, the seawall was attacked not only by the big waves which was propogate from the deep sea but also by the onshore strong wind speed which always induced a big increasing of wave run-up and produced an enormous amount of wave overtopping. Therefore, the study of the correlation between the onshore wind speed to the wave runup was need to understand.

Analytical Consideration

Based on the results of the dimensional analysis by Tsuchiya (1978), the correlation between the influence factors of wave run-up to the height of the relative run-up can be summarized as follows:

$$\frac{R}{H} = f_1\left(\frac{H}{L}, \tan\theta, \frac{h}{H}, \frac{d}{H}, \frac{\sqrt{K}}{H}\right) \quad \ldots\ldots\ldots\ldots(1)$$

where H: Incident wave height
L: Incident wave length
θ : Angle of the slopping dyke to the bed
h: Water depth before the toe of the slopping dyke
d: Roughness on the surface of the slopping dyke
K: Rate of percolation

Therefore, in case of the constant water depth, the smoothed slope dyke surface and the unpercolated dyke conditions, the above formula can be simplified as

$$\frac{R}{H} = f_2\left(\frac{H}{L}, \tan\theta\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

When a wave run-up on a breakwater and at its maximum condition, the flow velocities are essentially zero and all the energy of this run-up water is in the form of potential energy. By knowing the shape and position of this hypothetical runup wedge, this potential energy can be calculated. Cross and Sollitt (1972) proposed that the shape of the runup wedge is assumed to be a parabola with its vertex at the bottom of the first wave trough as shown in Fig.1.

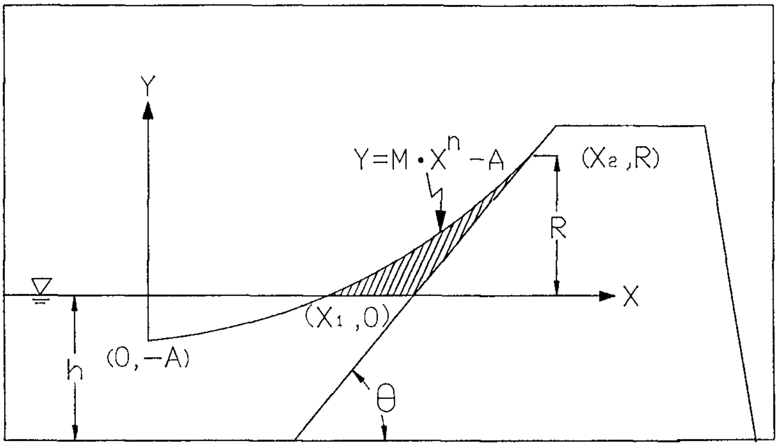

Fig.1 The shape of the runup wedge

The corresponding equation is

$$Y = M X^n - A \quad \text{.............................}(3)$$

in which Y is the water surface elevation above the still water level; X is the distance from the trough shoreward; A is the amplitude at the trough and M, n are the shape parameter.

It follows directly that the potential energy of the run-up wedge at maximum runup is simply as

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

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

$$= \frac{1}{2} \rho g \left\{ \frac{M^2}{2n+1} (X_2^{2n+1} - X_1^{2n+1}) - \frac{2 \cdot MA}{n+1} (X_2^{n+1} - X^{n+1}) \right.$$

$$\left. + A^2 (X_2 - X_1) - \frac{R^3}{3\alpha} \right\} \quad \text{........................}(4)$$

Two boundary condition can be obtained when the parabola run-up curve run across to the sea water level at point X_1 and the maximum run-up R at X_2. Therefore, from Eq.3 we known that:

$$R = M(X_2)^n - A \quad => \quad X_2 = \left(\frac{R+A}{M}\right)^{1/n}$$

$$0 = M \cdot X_1{}^n - A \quad => \quad X_1 = \left(\frac{A}{M}\right)^{1/n}$$

Substitute the above two boundary condition into Eq. 4, the potential energy of the wave run-up can to convert as

$$PE = \frac{1}{2}\rho g \left\{ \frac{M^2}{2n+1}\left[\left(\frac{R+A}{M}\right)^{(2n+1)/n} - \left(\frac{A}{M}\right)^{(2n+1)/n}\right] - \frac{2MA}{n+1}\left[\left(\frac{R+A}{M}\right)^{(n+1)/n} - \left(\frac{A}{M}\right)^{(n+1)/n}\right] + A^2\left[\left(\frac{R+A}{M}\right)^{1/n} - \left(\frac{A}{M}\right)^{1/n}\right] - \frac{R^3}{3\alpha} \right\} \quad \cdots\cdots\cdots\cdots(5)$$

As the water wave propagate across a fluid, it can transferred the energy flux. Based on the small amplitude wave theory, the average energy flux in unit width and over a wave period can be obtained as

$$TE = \frac{1}{8}\rho g H^2 \cdot L \cdot \left\{ \frac{1}{2}\left[1 + \frac{2kh}{\sinh(2kh)}\right]\right\} \quad \cdots\cdots\cdots\cdots(6)$$

By way of the assumption that the energy contained in the run-up wedge is evaluated from the net energy flux into a control volume which enclosing the runup wedge and the partial standing wave system, the related equation between the incident wave and the relative runup height can be expressed as

$$\frac{M^2}{2n+1}\left[\left(\frac{R+A}{M}\right)^{(2n+1)/n} - \left(\frac{A}{M}\right)^{(2n+1)/n}\right] - \frac{2MA}{n+1}\left[\left(\frac{R+A}{M}\right)^{(n+1)/n} - \left(\frac{A}{M}\right)^{(n+1)/n}\right] + A^2\left[\left(\frac{R+A}{M}\right)^{1/n} - \left(\frac{A}{M}\right)^{1/n}\right] - \frac{R^3}{3\alpha}$$

$$= C_e \cdot \frac{L}{4} H^2 \left\{ \frac{1}{2}\left[1 + \frac{2kh}{\sinh(2kh)}\right]\right\} \quad \cdots\cdots\cdots\cdots\cdots\cdots(7)$$

where C_e indicate the coefficient of energy loss by the influence of surface and bottom frictions during the process of the wave run-up.

In accordance with the above mentioned equations, if the value of M, n and C_e can be identified from surf parameter then by trial and error method, the height of the wave run-up can be computed.

On the heels of the effect on wind speed to wave run-up. The first thing must to determined was the additional wave which was induced by the strong wind that was blowing from the seaside to the shoreline during the tyhpoon season. Falvey (1974) using the momentum balance method over a control volume which includes the boundary layer of the air and the statistical relationship for the significant wave height. He suggested a correlated equation between the significant wave height, the wind speed and the fetch length as follows:

$$H_{1/3} = (3.1x10^{-7} \cdot U_{10}^{2} + 1.6x10^{-3} \cdot U_{10}) \cdot \left(\frac{F}{g}\right)^{1/2} \quad \ldots\ldots(8)$$

in which U_{10} is the onshore wind speed at the height of 10 meters from the still water level and F is the fetch.

If F is measured in kilometers, U_{10} in meters per second, $H_{1/3}$ in meters and with g=981 cm/s², the above equation becomes

$$H_{1/3} = (3.1x10^{-4} \cdot U_{10}^{2} + 1.6x10^{-2} \cdot U_{10})\sqrt{F} \quad \ldots\ldots\ldots(9)$$

At last, the work of the combination of the incident wave and the additional wave which was induced by the onshored strong wind must to determined. Due to the phenomenalism of wave-wave interaction is not so distinct. Therefore, the method of the linear addition of the wave energy was choiced to applied for temporary.

Experimental Equipment and Procedures

Experiments were conducted in a wave tank 15 meters long, 40 cm wide and 80 cm deep. Both walls of the wave tank are constructed of strengthed glass throughout and the bottom is constructed of stainless steel of a plane surface. A blower was installed just upon the wave maker at one end of the tank while the sloping dyke model was constructed at the another end as shown in Fig.2.

The incident wave characteristics were measured using a capacitate wave gage at the location where the toe

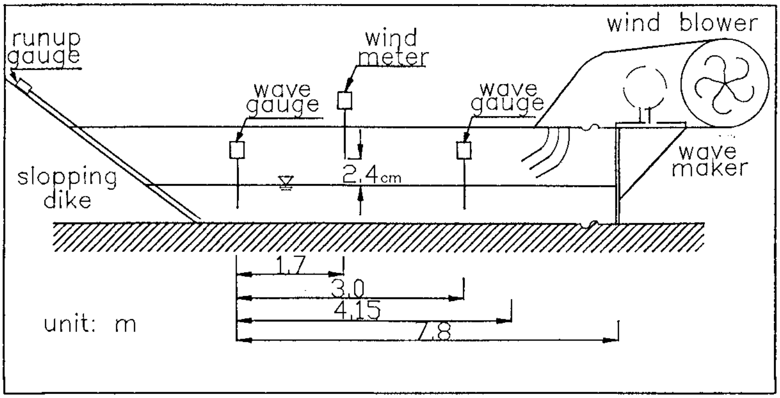

Fig.2 Diagram of Experimental Facility

of the structure was placed and the runup wave was measured on the inclined dike surface at the same way.

In experiment, the slope of the wave tank was maintained at horizontal and four kinds of dike slope (1:0.5, 1:1, 1:2 and 1:3) was choiced and the tests of the wind speed from 0 to 16 meters per second accompany with some range of wave steepness was completed.

Results and Discussion

By way of the analysis to the wave run-up pictures which was taken from the experiments in different kind of conditions (many kinds of dike slope and different kind of the incident wave steepness). We can find that the parabola shape of the wave runup was influenced by the surf parameter ξ ($=\tan\theta / \sqrt{H/L}$). The correlation between the shape parameters of the parabola runup M, n and the surf parameter ξ was shown in Fig.3 and 4 separately. From those figures, we can systematic out the following relationship between ξ to M and n in some kind of the dike slope.

(1) $S = 1:0.5$; $M = 54.226\,\xi^{-3.5}$

$n = 1.0075\,\xi^{0.1909}$

(2) $S = 1:1$; $M = 5.993\,\xi^{-3.683}$

$n = 0.608\,\xi^{0.5865}$

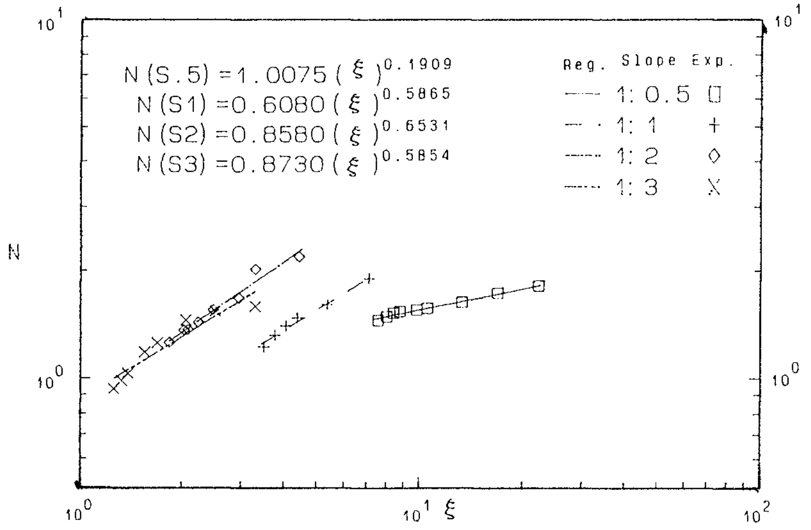

Fig.3 Correlation between M and ξ

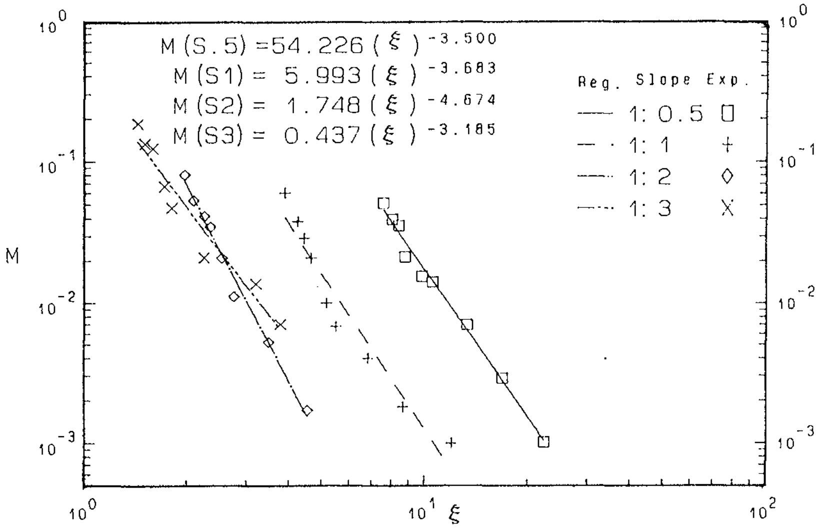

Fig.4 Correlation between n and ξ

(3) $S = 1:2$; $M = 1.748\,\xi^{-4.674}$

$n = 0.858\,\xi^{0.6351}$

(4) $S = 1:3$; $M = 0.437\,\xi^{-3.185}$

$n = 0.873\,\xi^{0.5854}$

As to the effect on the onshore wind speed to the relative wave runup height, the results of the computation and the experiment was shown in Fig.5 (1)-(4). In those figures, we can find that in steep slope, for example when the dike slope is 1 to 0.5 and 1 to 1 with vertical to horizontal, the relative wave run-up will decreased first to some degree then increased when the value of the wind parameter ($U/\sqrt{gH_0}$) was increased. But in gentle slope, that is the slope of the dyke is 1 to 2 and 1 to 3, the relative wave runup height was increased almost immediately when the value of the wind parameter was increased.

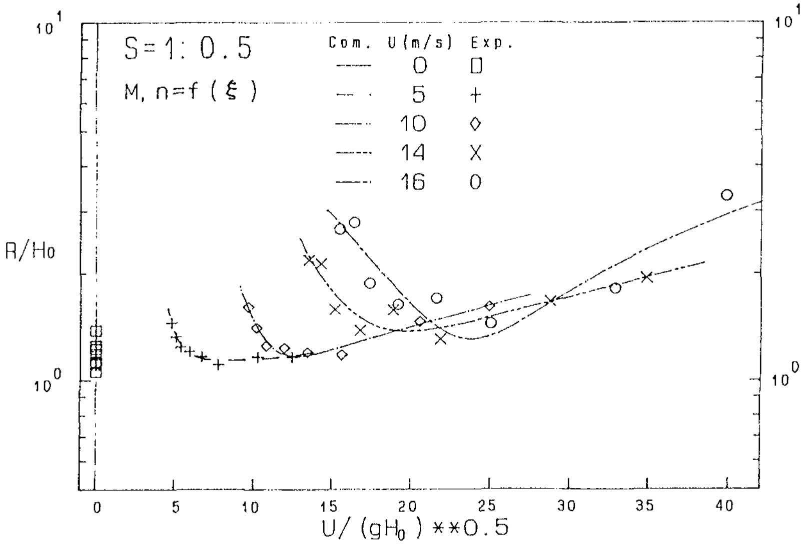

Fig.5 Correlation between the relative runup and the wind parameter (1)

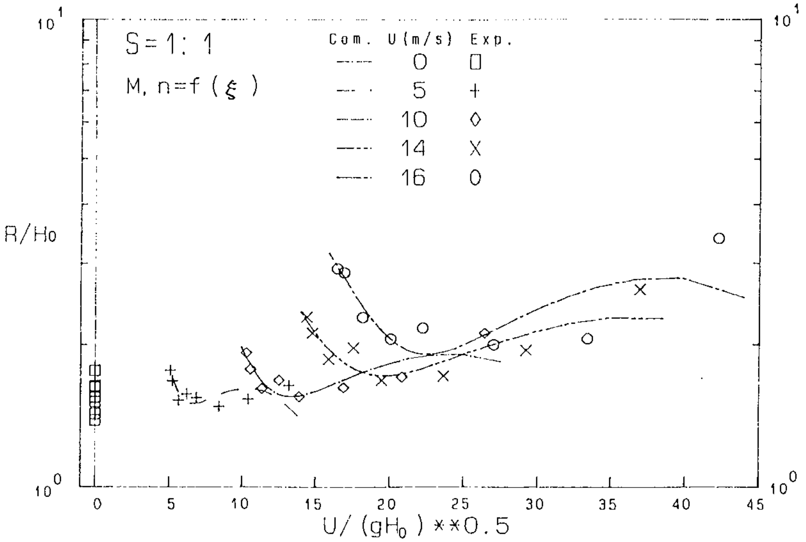

Fig.5 Correlation between the relative runup and the wind parameter (2)

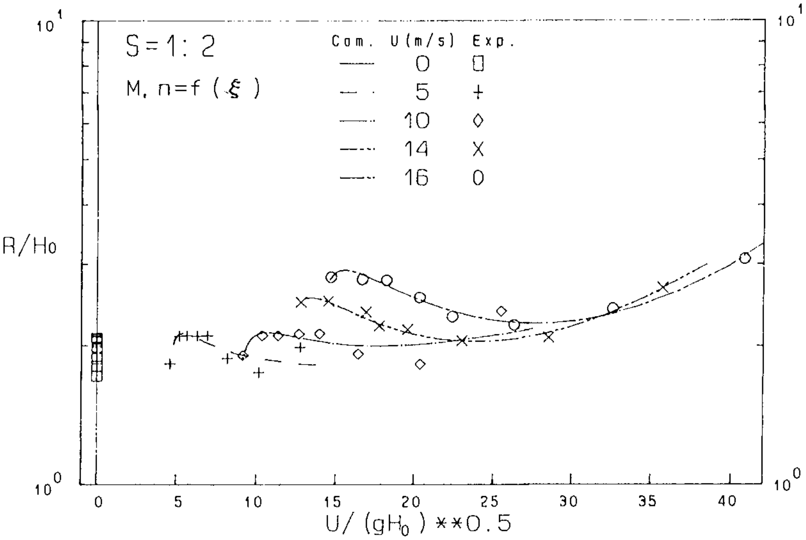

Fig.5 Correlation between the relative runup and the wind parameter (3)

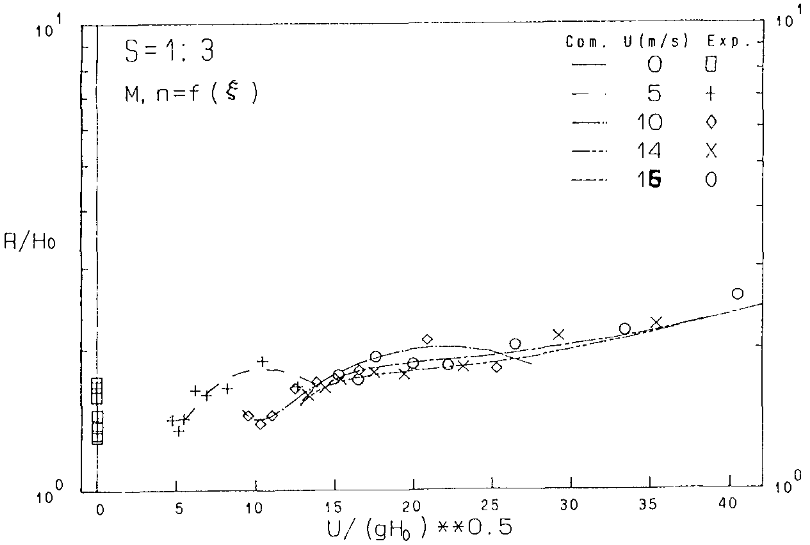

Fig.5 Correlation between the relative runup and the wind parameter (4)

If we pay the another attention to the incident wave steepness to stand for the wind parameter. The effect on the onshore wind speed to the relative wave runup height can be find as shown in Fig.6(1)-(4). From those figures, we can understand that the effect on the onshore wind speed to the relative wave runup height was more obviously in steeper slope (S=1:0.5, 1:1) than in milder slope (S=1:2, 1:3). However,the relative wave runup height will be increased when the onshore wind speed was increased are doubtless as shown in those figures. However, in general speaking, in spite of the strength of the wind speed, the relative run-up becomes the biggest when the dyke slope was 1:2.

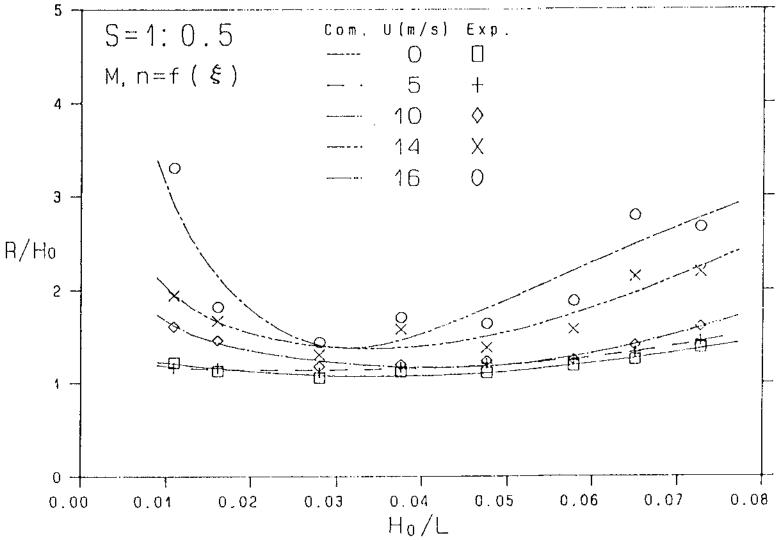

Fig.6 Correlation between the relative runup and the incident wave steepness (1)

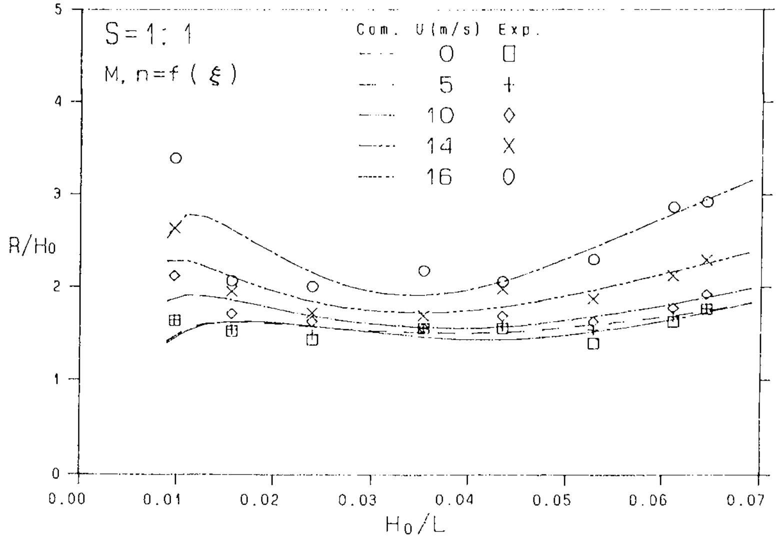

Fig.6 Correlation between the relative runup and the incident wave steepness (2)

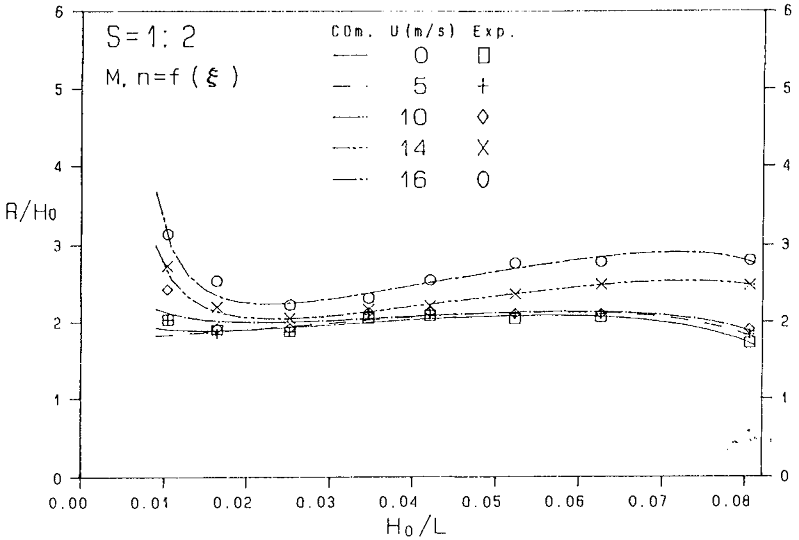

Fig.6 Correlation between the relative runup and the incident wave steepness (3)

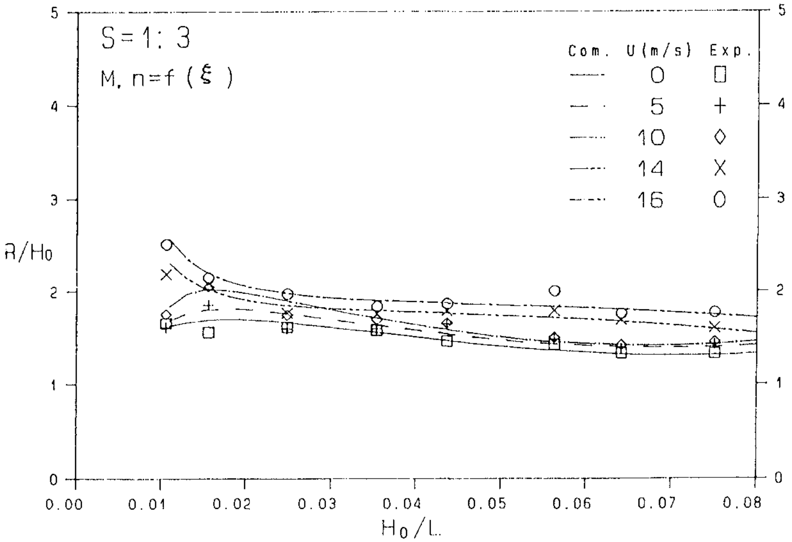

Fig.6 Correlation between the relative runup and the incident wave steepness (4)

Conclusions

(1) The parabolic shape of the wave runup was quite unsimilar in the condition of the different dyke slope and the incident wave steepness.
(2) The exponential value in the relationship between n and the surf parameter ξ was between 0.19 to 0.65.
(3) The effect on the onshore wind speed to the relative wave runup height was more abviously in steeper slope than in milder slope.
(4) In general speaking, in spite of the strength of the wind speed, it is remarkable that the relative run-up becomes the biggest when the dyke slope was 1:2.

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