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THE STUDY ON WAVE RUN-UP ROUGHNESS AND PERMEABILITY COEFFICIENT OF STEPPED SLOPE DIKE

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ABSTRACT: In this paper, a special kind of revetment stepped revetment which is a new roughening method-is discussed. And this paper studies the different influence of step height on wave run-up and wave absorbing characteristic through physical model test. Then the recommended values of different relative step height dikes' roughness and permeability coefficient are given. The data shows that the roughness and permeability coefficient is about 0.5. The stepped slope dike is with good wave dissipation effect. Then the data shows that the minimum roughness and permeability coefficient exists with the trend of wave run-up first decreasing and then increasing with the increase of relative step height. Thus ,the paper can serve as a reference for the engineering design.

Keywords: Stepped slope dike roughness and permeability coefficient relative step height wave run-up

INTRODUCTION

Slope dike has used widely in coastal engineering. There are many researches on the wave run-up of this structure[1]. While there are some disadvantages of this structure such as higher wave run-up ,higher dike elevation in flood protection of the important cities, spending more engineering materials and affecting the cities landscape sometimes. In recent years, stepped seawall has been used in the flood protection of some cities. This kind of structure is simple and beautiful ,and is used as a tourist leisure venues usually and can resist stormy waves during the typhoon period.However, there is few studies on the structure of the wave run-up.

This paper,applying the traditional wave run-up formula of slope embankment, determines the roughness and permeability coefficient of stepped seawalls structure with modeling experiments. It can be applied in engineering design for the estimation of wave run-up.

THE GENERAL FORMULA TO DETERMINE THE ROUGHNESS AND PERMEABILITY COEFFICIENT

In regular waves ,the wave run-up formula can be expressed as following[2]:

$$R = K_\Delta R_1 H \quad (1)$$

$$R_1 = K_1 \mathrm{th}(0.432\mathrm{M}) + [(R_1)_\mathrm{m} - \mathrm{K}_2]\mathrm{R(M)}$$

$$\mathrm{M} = \frac{1}{\mathrm{m}}\left(\frac{L}{H}\right)^{1/2}\left(\mathrm{th}\frac{2\pi d}{L}\right)^{-1/2}$$

$$(R_1)_\mathrm{m} = \frac{K_3}{2}\mathrm{th}\frac{2\pi d}{L}\left(1 + \frac{4\pi d / L}{\mathrm{sh}\frac{4\pi d}{L}}\right)$$

Where:

R = wave run-up ,from the static water level, upward is positive

H = wave height

M = the function about the slope value m

R(M) = the wave run-up function

K_Δ = roughness and permeability coefficient

K_1, K_2, K_3= coefficient

R_1 = wave run-up when K_Δ=1,H=1

$(R_1)_m$ = maximum wave run-up corresponding the d/L

The values of K_1,K_2,K_3 are determined as following:

K1	K2	K3
1.24	1.029	4.98

The roughness and permeability coefficient can be obtained by (1):

$$K_\Delta = \frac{R}{R_1 H}$$

Ordering the roughness and permeability coefficient of the smooth dike in the test is $K_{\Delta 0}$, determined by the type. Owning to the material limitation in the test, the roughness and permeability coefficient of the smooth dike is not equal to 1. So the end permeability coefficient values of other slope dikes with steps are determined by the follow formula

$$K_{\Delta}* = \frac{K_{\Delta}}{K_{\Delta o}} \quad (2)$$

THE EXPERIMENTAL EQUIPMENT AND EXPERIMENTAL METHOD

Model tests are carried out in a wave flume(figure 1), wave flume length is 40m ,height is 1m width is 0.8m.On one end provided with a push plate irregular wave maker, the wave maker system can make a variety of regular waves with diffident wave heights and diffident wave period. The wave parameters is measured by resistance-type wave gauge. The wave run-up on the slope dikes is recorded by observing the videos shooting by HD camera (in the case of no wave overtopping). The models are designed using the gravity similarity criterion in the test.

The parameters in the test are as follows: slope dikes with six kinds of step height (dh=0.01m 0.022m 0.044m 0.088m,0.176m,0m (the smooth slope dike)). In the case of 9 groups regular waves (T=0.8s, 1.0s, 1.3s .H=0.048m, 0.061m, 0.08m) and 0.73 water level ,the wave run-up are measured.

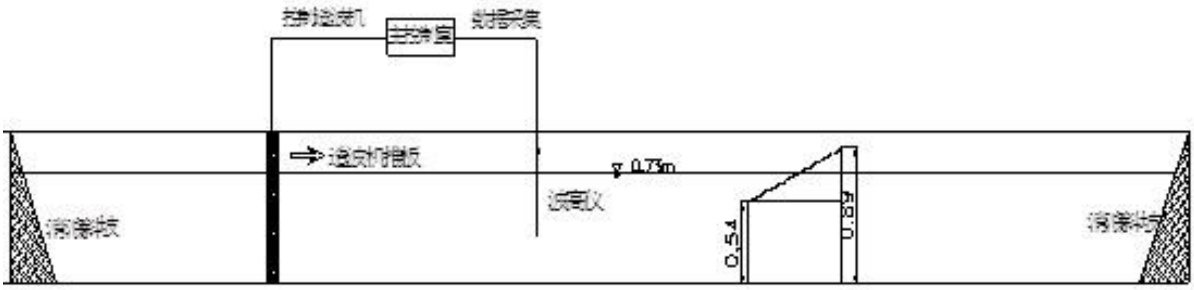
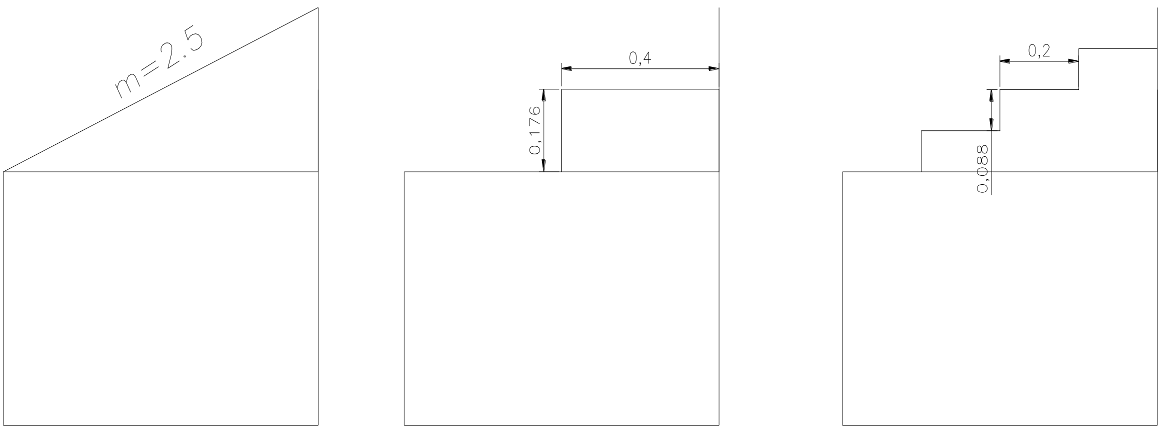


Figure 1. wave flume with modeling layout and instrument locations



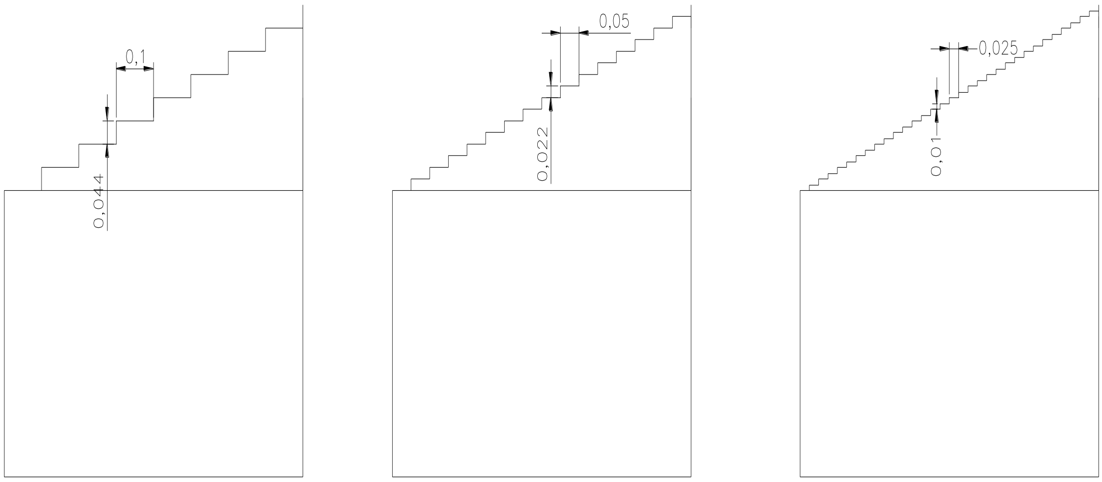


Figure 2. Schematic diagram of the model

EXPERIMENT RESULTS AND ANALYSIS

In the description of the roughness and permeability coefficient of stepped slope dikes, the relative step height (dh/h) is introduced. The relative step height is the ratio between step height and the total height of slope dike. We think the roughness and permeability coefficient is the same when the slope value and the relative step height are the same.

The roughness and permeability coefficient and wave relative run-up are arranged in the following table. The ultimate recommended values of the roughness and permeability coefficient is the average value of the coefficient values in the table 3. Summarizing in the following table.

Table 1. the roughness and permeability coefficient

period	dh / H	0.01	0.022	0.044	0.088	0.176	Smooth slope dike
0.8s	0.047	0.68	0.484	0.533	0.783	0.501	1.044
	0.062	0.771	0.596	0.635	0.807	0.589	1.179
	0.072	0.849	0.679	0.747	0.976	0.696	1.273
1.0s	0.048	0.598	0.439	0.407	0.622	0.351	0.997
	0.062	0.602	0.455	0.535	0.595	0.421	1.003
	0.081	0.597	0.495	0.545	0.683	0.545	——
1.3s	0.048	0.231	0.213	0.228	0.261	0.172	0.400
	0.062	0.225	0.200	0.209	0.252	0.180	0.360
	0.081	0.213	0.234	0.209	0.216	0.209	——

Table 2. The relative wave run-up of diffident relative step height

Relative step height	0	0.029	0.063	0.126	0.251	0.503
	2.13	1.45	0.99	1.09	1.60	1.02
	2.10	1.37	1.06	1.13	1.44	1.05
	2.08	1.39	1.11	1.22	1.60	1.14

Relative run-up（R/H）	2.60	1.56	1.15	1.06	1.63	0.92
	2.42	1.45	1.10	1.29	1.44	1.02
	0.00	1.28	1.07	1.17	1.47	1.17
	2.81	1.63	1.50	1.60	1.83	1.21
	2.58	1.61	1.44	1.50	1.81	1.29
	0.00	1.75	1.63	1.46	1.51	1.46

Table 3. The roughness and permeability coefficient of the relative step height

Relative step height (dh/h)	0	0.029	0.063	0.126	0.251	0.503
Coefficient (K_Δ*)	1	0.68	0.46	0.51	0.75	0.48
	1	0.65	0.51	0.54	0.68	0.5
	1	0.67	0.53	0.59	0.77	0.55
	1	0.6	0.44	0.41	0.62	0.35
	1	0.6	0.45	0.53	0.59	0.42
	1	0.58	0.53	0.57	0.65	0.43
	1	0.63	0.56	0.58	0.7	0.5

Table 4. The recommended permeability values of diffident relative step height

Relative step height	0	0.029	0.063	0.126	0.251	0.503
Coefficient (K_Δ*)	1	0.63	0.50	0.53	0.68	0.46

From the data in the table 4 , it shows that the dissipation effect is very good though the roughening method of constructing steps on the surface of slope dike. The wave run-up can be reduced about 50%.

To analysis the change trend of wave run-up and roughness and permeability coefficient with the increase of relative step height ,table 2 and table 3 are designed graphs.

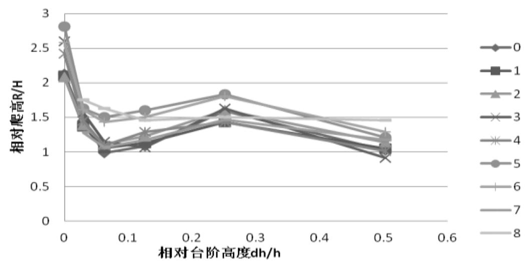


Fig. 3

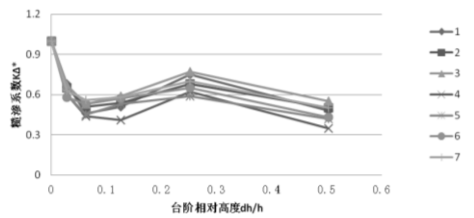


Fig. 4.

From figure 3and figure 4 it can be seen that when dh/h<0.25, the variation trend of wave run-up and roughness and permeability coefficient is first decreased and then increased with the increasing relative step height. Therefore ,it exists the minimum permeability coefficient when the relative step height reach the critical value. In the modeling experiment, when dh/h=0.063, the permeability coefficient reach the minimum value, K_Δ =0.5,reaching good wave dissipating effect. This point has a positive reference value for engineering applying the appropriate relative step height value to reaching the better wave absorbing effect.

When dh/h>0.25, the permeability coefficient decreases. In the case of dh/h =0.503, just one step in the experiment, it is diffident from other relative step height in this case. The wave absorbing characteristics in this case is same with the slope dike with the berm of steep slope seawall.

At this time, the wave run-up on this structure is influenced by the factors of water depth on the step and step width. The paper of Effect of the berm of steep slope seawall on irregular wave run-up(LU ruixing)[4] points out that when the slope value of seawall m=0-0.4, the slope value is almost no influence on wave run-up reduction. They obtained the formula:

$$-0.5 \le d_B/H_S \le 0, \tag{3}$$

$$K_{BO} = 1 - \frac{B}{B + 6H_S} = 1 - \frac{B/H_S}{B/H_S + 6}$$

Where :
K_{BO} = run-up reduction coefficient
B = platform width
Hs = significant wave height

In the experiment ,the underpart breakwater is vertical breakwater, so m=0, B=0.4m, H=0.08m, 0.062m, 0.048m. Then we can get the average wave run-up reduction coefficient Kb=0.48. This reduction coefficient is closed to the permeability coefficient (K_{Δ}=0.46) we obtained in the experiment. And the experiment of LU Rui-xing shows that when the step width remains unchanged, the wave run-up reduction reach the minimum value when the berm lying at the still water level. From this point, the permeability coefficient we obtained in the experiment is consistent with the actual in the case of just one step.

CONCLUSION

A new kind of revetment-stepped revetment which is a new roughedning method –is presented in this paper. The slope dike of this structure is in accord with the social trends that human live in harmony with nature.

Because this type of structure doesn't need too much concrete anisotropic block. It is convenient for people to repair the slope dike because we can walk on it. The most important thing ,this kind of pavement structure has good wave absorbing effect proved by the modeling experiment. The recommended permeability coefficient value is given in this paper. This can serve as a reference for the engineering design.

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