Optimum Size of Distorted Ripple Train for the Control of Cross-shore Sediment Transport

Satoshi Takewaka[1], Isao Irie[2], Masahiro Uchida[3], Hirokazu Sakamoto[4] and Nobuyuki Ono[5]

Abstract

The Distorted Ripple Train System, which is aimed to control the cross-shore sediment transport, is proposed. The concept and basic functions of the artificial ripple system are introduced in the study and a detailed discussion is given on the determination of the optimum size of the individual ripple which enhance the effect of control.

Introduction

This study examines the basic function and determines the optimum size of the Distorted Ripple Train System (**Fig.1**), which is developed to control the flow and sediment movement near the bottom. The form of the individual artificial ripple resembles to a natural ripple, but its asymmetry is exaggerated and the steep side faces offshore. The difference of the scale and strength of the detached vortices which are formed behind the ripple crest during one wave cycle, being large when the water particle travels offshore, is the agency for the emergence of onshore directed steady flow and sediment transport.

One possible application of the Distorted Ripple Train System is its installation in front of a nourished beach which will endure the effect the nourishment (**Fig.2**). Offshore directed sediment, which becomes active just after the nourishment, will be trapped and transported shorewards on the Distorted Ripple Train System.

[1]Assistant Prof., Inst. of Engineering Mechanics, Univ. of Tsukuba, Japan 305–8573.
[2]Prof., Department of Civil Engineering, Kyushu Univ., Japan 812-8581.
[3]Engineer, Japan Railway Construction Company.
[4]Graduate Student, Department of Civil Engineering, Kyushu Univ.
[5]Research Assistant, Department of Civil Engineering, Kyushu Univ.

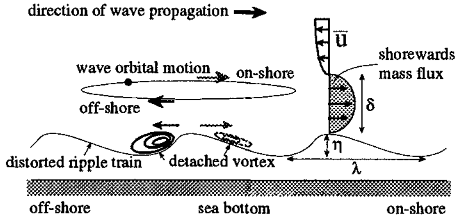

Figure 1 Conception of Distorted Ripple Train System

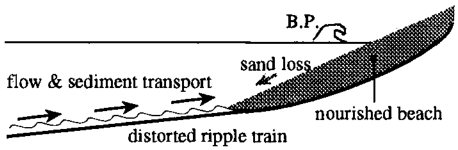

Figure 2 Idea of an application of the Distorted Ripple Train System

Part of this study is originated from the idea of Inman and Tunstall (1972) who have studied basic functions of asymmetrical ripple-like roughness element. No succeeding research, however, was reported to the author's knowledge.

While the general result obtained thus far by our research group is reported by Irie et al. (1998), this study concentrates on how the size of the individual ripple in the train system should be determined to maximize the performance of the sediment control. To this aim, results of laboratory experiments and numerical computations are presented in this paper .

Laboratory tests

The length λ $(= 0.055m)$ and height η $(= 0.01m)$ of the individual ripple in the train system were set as a trial equal to the length and height of a natural ripple formed in a movable bed experiment with water depth $h = 0.35m$, wave period $T = 1.5s$, wave height $H = 0.08m$ and sand diameter $= 0.16mm$. The horizontal asymmetry is fixed tentatively to $1 : 3$. Another train with ripples of same configuration but enlarged two times in dimensions $(\lambda = 0.11m,\ \eta = 0.02m)$ was also prepared. The train of the distorted ripple was set in the bottom of the wave flume extending $6m$ in length.

Experiments were conducted by changing the wave condition $(0.05m < H < 0.09m,\ 0.8s < T < 2.0s)$. Vertical distributions of horizontal velocity u above the ripple crest were measured with laser-doppler velocimeter. **Fig.3** shows an example of the measurement, which indicates that the steady flow U

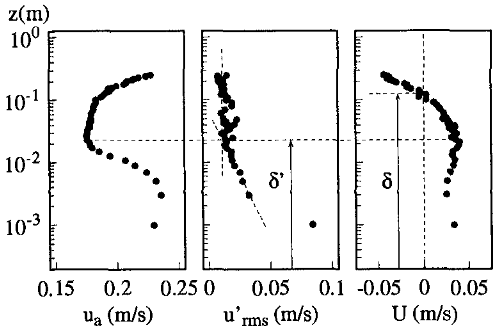

Figure 3 Velocity distribution above ripple crest.
u_a : wave velocity amplitude, u'_{rms} : turbulent intensity, U : steady flow.
Experimental condition : T=1.5s, H=0.08m, h=0.35m.

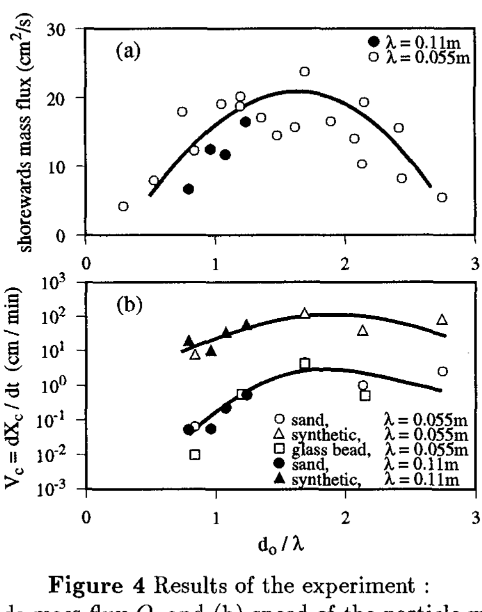

Figure 4 Results of the experiment :
(a) Shorewards mass flux Q, and (b) speed of the particle movement V_c, versus d_o/λ.

near the bottom is directed shorewards extending to the height δ. The amount of the onshore directed steady flow = shorewards mass flux $Q = \int^{\delta} U$ varied

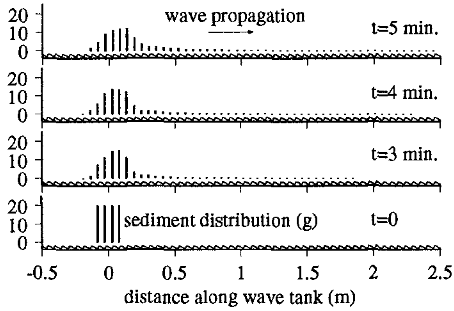

Figure 5 Movement of particle(fine sand) above distorted ripple train. Experimental condition : T=1.5s, H=0.08m, h=0.35m.

in accordance with the wave condition. This variation is depicted in **Fig.4(a)** with the horizontal axis being the ratio of water particle orbital diameter d_o to ripple length λ. The flow becomes intense when d_o/λ approaches 1.7, which is equivalent to the wave condition of the movable bed experiment mentioned before.

Movements of particles above the train were observed and their speed was measured. Three types of particles were used in the tests : glass bead (diameter : 0.08mm, specific gravity : 2.6), fine sand (0.16mm, 2.6) and synthetic particle (0.32mm, 1.6). Particles of 20g in weight were placed above the trough of the ripple at the rest. Particles moved and scattered shorewards as a whole after the wave action in all experiments (**Fig.5**). On and offshore distributions of scattered particles were measured and the variation of their centroid position X_c and dispersion width were recorded. **Fig.4(b)** shows the result of experiments, where the vertical axis is the variation of centroid in time $V_c=dX_c/dt$. The movement of particles shows a tendency to become intense when d_o/λ approaches 1.7, which agrees well with the characteristics of steady bottom flow variation described before.

The result of the experiments suggests that an effective sediment control is achieved when the ratio of the orbital diameter of the wave motion to ripple length d_o/λ approaches 1.7, which suggests that the size of the individual ripple in the train should be set identical to the size of the natural ripple. This finding will help the determination of the size of the ripple in practical application.

Numerical computation

System of equations for stream function ψ and vorticity ω was solved numerically introducing turbulent diffusion coefficient. Curvilinear grid system and finite difference method were employed. There is a limitation in the nu-

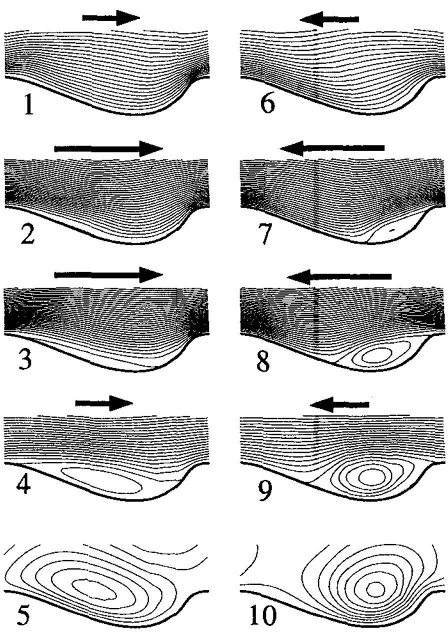

Figure 6 Variation of ψ during one oscillatory flow cycle

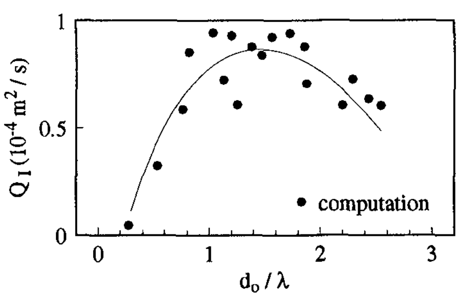

Figure 7 Variation of Q versus d_o/λ

merical work : the computation is conducted under oscillatory flow condition, where the real phenomenon occurs under wave motion. This restricts the direct comparison between the experimental and computational results, however, our primary concern in the computational work is to catch the change of vortex shedding pattern and shorewards mass flux according to the external flow condition variation.

Figure 6 shows a typical result of the computation. The stream function distribution are depicted with contour lines. The vortex shedding from the ripple crest is observed, being asymmetric in one oscillatory flow cycle. The magnitude of the vortex can be estimated roughly by counting the number of isolines and it is evident that the vortex formed above the steep slope is more energetic.

A large number of computation was conducted by varying the oscillatory flow condition, the oscillatory period and excursion length. **Figure 7** shows the variation of the amount of shorewards mass flux according to external flow condition change. The steady mass flux reaches a maximum when d_o/λ approaches 1.6, which is the same tendency with the experiment.

There remains some points to be refined in the computational work, however, the potential of the numerical approach have been demonstrated.

Conclusion

The performance of the Distorted Ripple Train System, which is aimed to control the bottom flow field and sediment transport, have been demonstrated through laboratory experiments and numerical computations. The optimum size of the individual ripple was determined from the experimental results. The flow and sediment control become effective when the wave condition approaches $d_o/\lambda \sim 1.7$, which suggests that the optimum size of the individual ripple should be set identical to the size of the natural ripple.

References

Inman, D.L. and Tunstall, E.B. (1972) : Phase dependent roughness control of sand movement, Proc. 13th ICCE, pp.1155–1171.

Irie I., S. Takewaka, N. Ono, K. Murakami, H. Sakamoto and O. Shimada (1998) : Retaining beach sand by a distorted ripple mat, Int. Conf. on Coastlines, Structures and Breakwaters, The Institution of Civil Engineers, London.