CS-63

Current Deformation due to a Superimposed Wave on a Smooth Bottom

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1 Introduction : In coastal environments the problems of siltation and erosion are caused by the waves superimposed on a current. The transport of sediment is governed by the current, while the suspension of the particles is due to wave action. It is, therefore, important to investigate the change in the current profile by superimposed wave motion, to describe the sediment transport with reasonable accuracy.

2 Experimental Conditions : The past experimental studies have been made in wave flume, which inherits the complications like; the waves are nonlinear and irregular, the effect of mass transport exists, the accurate measurement of boundary layer thickness is not possible, the wave velocity amplitude needs adjustment under combined flow in order to obtain the same amplitude as under pure wave motion. Therefore, in the present study, an oscillating tunnel equipped with a centrifugal pump to generate steady flow is utilized to overcome the above problems. The description and layout of the experimental setup is presented in Sugiki et al.(1995).

The experimental conditions are presented in Table 1.

Table 1. Experimental conditions for the data used in the present study

Experiment	T(sec)	$\hat{U}_w$(cm/s)	$\bar{u}_c$	$R_c = \bar{u}_c z_h/\nu$	RE=$\hat{U}_w^2 T/2\pi\nu$	Remarks
C01	-	-	8.43	2217	-	pure current
B03	3.03	83.64	8.93	2348	2.95×10^5	combined
B05	2.84	116.84	8.92	2345	5.40×10^5	combined

In most of the analytical and numerical models for wave-current combined motion , the current profile is assumed to be logarithmic and unchanged even after superposition of wave motion. But as demonstrated by earlier and present experiments, the current profile undergoes a change due to wave component. Therefore to allow for a nonlinear interaction of wave and current, the famous low Reynolds number k-ϵ model by Jones and Launder (1972) has been applied to compare the results with the present experimental data.

3 Results and Comparison : To validate the $k-\epsilon$ model for the combined flow experimental conditions, the velocity profile for case B05 is presented in Fig.1. It can be observed that the model agrees well with experiment, except in the near wall region, where the velocity gradient is underestimated by the model. Fig.2 shows the wave velocity amplitude and phase difference for case B05 and pure wave motion. It can be observed that the wave boundary layer remains unchanged in the combined flow. The experiment shows abrupt change in the period averaged velocity profile at $z=\delta$, where, δ is the thickness of wave boundary layer as per Jonsson's definition(Fig.3 and 4.), which can be attributed to the momentum transfer from high velocity region towards the wall. The model prediction in case B03 is good in the region beyond $z=\delta$, but for case B05 the model could not predict the abrupt change in the period averaged velocity profile. Fig.5 and 6 show the period averaged fluctuating velocity in x-direction. Since, the model provides turbulent kinetic energy, the fluctuating velocity was estimated using the approximation employed by Justesen (1987). The predicted values near the wall are underestimated, but overall agreement is good. It may be noted that against the usual assumption in two layer models for wave-current flow, the fluctuating velocity beyond the wave boundary layer does not approach the value pertaining to pure current case. The temporal variation of the bottom shear stress (Fig.7 and 8) shows underestimated value by the model, along with a difference of phase.

4 Conclusions : The k-ϵ model should be refined to be able to predict the high Reynolds number combined flow with reasonable accuracy. In the development of an analytical model for the combined flow, the zone beyond wave boundary layer must not be considered to be dominated by the steady flow, but a combined effect of both wave and current may be considered.

References

Jones, W.P. and Launder, B.E., 1972, Intn'l J. of Heat and Mass Transfer, vol.15, pp.301-314.
Justesen, P., 1987, Series Paper No.43,Technical Univ. of Denmark.
Sugiki, N., Sana, A., Yamaji, H., Tanaka, H., 1995, 48th Conf. of JSCE(Tohoku Branch).

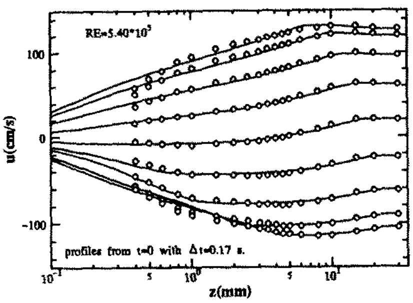

Fig.1 Velocity Profile for case B05

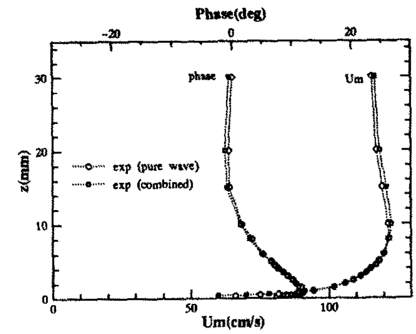

Fig.2 Comparison of pure wave and combined motion for case B05.

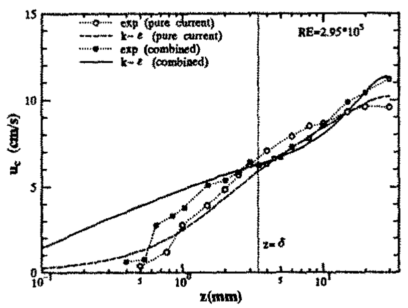

Fig.3 Period Averaged Velocity Profile for case B03

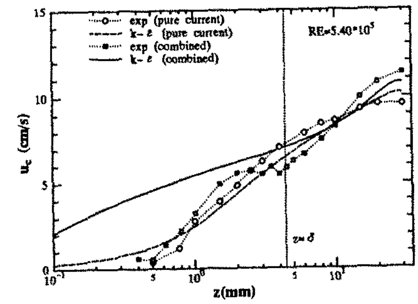

Fig.4 Period Averaged Velocity Profile for case B05

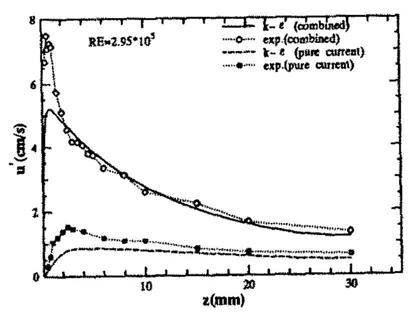

Fig.5 Period Averaged Velocity Fluctuation in X-Direction for case B03

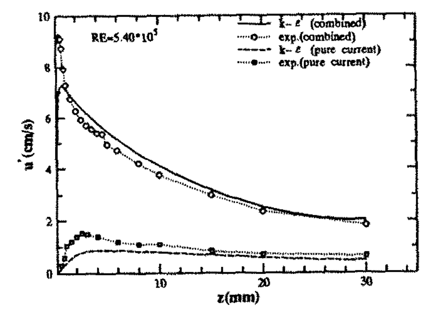

Fig.6 Period Averaged Velocity Fluctuation in X-Direction for case B05

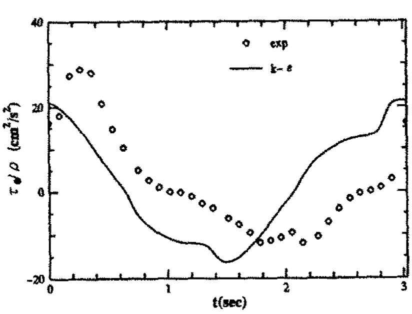

Fig.7 Temporal Variation of Bottom Shear Stress for case B03

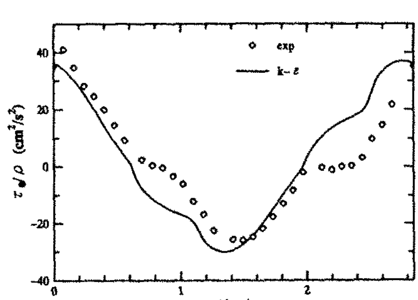

Fig.8 Temporal Variation of Bottom Shear Stress for case B05