CHAPTER 42

THE MASS TRANSPORT OF WAVES PROPAGATING ON A SLOPING BOTTOM

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ABSTRACT

This paper presents the experimental results on Eulerian mass transport which is induced by waves propagating on a sloping bottom . The measurements are carried out by laser Doppler velocimeter(LDV) in wave flume. A particular installation of measuring system is required to detect the boundary layer flow extremely close to the point of 0.15mm above the sloping bottom . From the experimental results , it is clear to see that the off-shore mass transport takes place inside the region from the proximity of bottom up to wave trough.Around the elevation of wave trough,the mass transport velocity changes its direction to on-shore raidly , and it reaches the maximun value at still water level , then it decreases to zero at crest.Further,the vertical distribution and similarity profile of Eulerian mass transport inside boundary layer are also obtained and discussed in this paper.

1. INTRODUCTION

Eulerian mass transport of wave shoaling process is a

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very important hydrodynamics,which is closely related to the on-shore and off-shore sediment transprot, the vertical distribution of suspended materials and the dispersion of pollutants in coastal waters.Within the last decade,Watanabe et al. (1980), Isobe and Horikawa(1981) and Nadaoka et al. (1982) employed hot-film anemometer and LVD (Laser Doppler Velocimeter) to measure the Eulerian mass transport in wave tank, respectively. Moreover, Sleath(1984) detected the mass transport inside boundary layer as wave propagating on a rough bed. Although the previous studies paid more attention on Eulerian mass transport of wave motion, however,the characteristics of mass transport of waves propagating on a sloping bottom has not been fully understood. Accordingly,in this paper the mass transport of wave shoaling from crest through the bottom , including the bottom boundary layer are detected by LDV and the results are disussed.

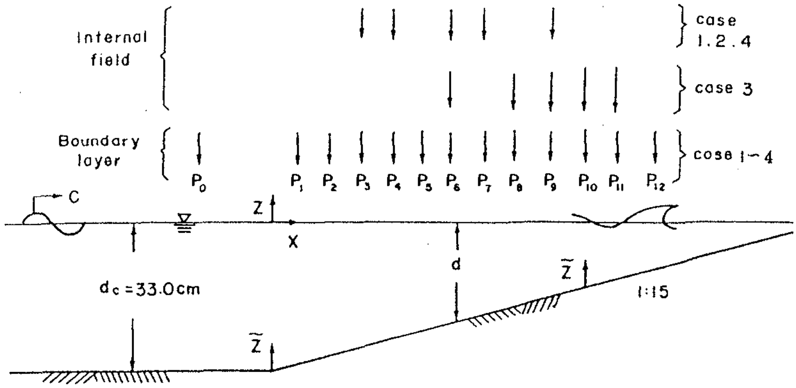
2. EXPERIMENTS

The experiments were carried out in a 9.5m×0.7m×0.3m wave tank in which the bottom was adjusted on one-fifteenth slope . The testing sections of internal field and boundary layer of waves shoaling on the sloping bottom are skectched in Fig.1 . Four kinds of wave steepness were made in wave flume and the experimental conditions are listed in Table 1. In

Table 1. The experimental conditions

case	T (sec)	H (cm)	d_c (cm)	H_0/L_0	Breaker
1	1.41	5.3	33.0	0.0186	plunging
2	1.23	6.6	33.0	0.0313	plunging
3	0.96	5.3	33.0	0.0405	plunging
4	0.96	8.2	33.0	0.0617	spilling

order to understand the distribution of mass transport , it had more fifty points measured by LDV in every testing section. Especially in the boundary layer within about 0.5cm height, it even had twenty-five measuring points detected by LDV in the experiment.



	P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}
d(cm)	33.0	22.8	19.6	17.4	15.7	14.5	13.0	11.4	11.0	9.8	8.5	7.4	6.1

Fig.1 The sketch diagram of testing sections.

Because the light beam of LDV system would be obstructed by the edge of sloping steel plate in the proximity of the bottom, that a particular installation of LDV system was required in order to detect the flow fields extremely close to the point of 0.15mm above the sloping bottom . The sketch diagram of the measuring installation is shown in Fig.2 . According to the experience , water quality control is very important for the fluid dynamic experiments employed by LDV. In this paper two sets of 5 μm filter screen are used to remove the larger natural particles suspended in water before the fresh water discharges into wave flume. After that , the signals drop-out would be reduced and the experimental quality would keep in good condition.

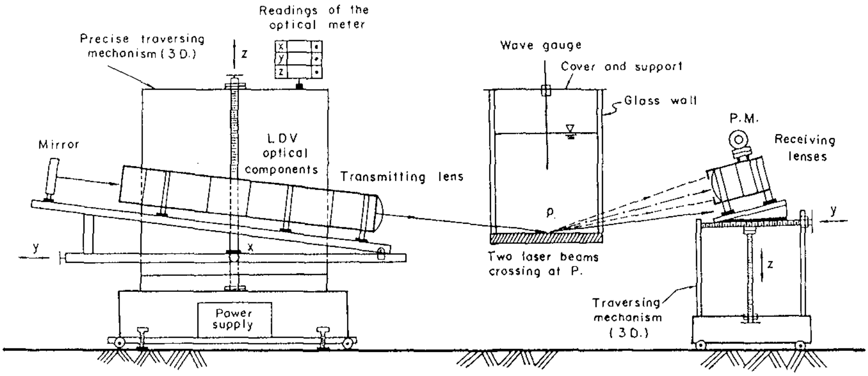


Fig.2 The sketch diagram of measuring installation.

The water surface elevation and the corresponding water particle velocity from crest through bottom were detected by wave gages and LDV simultaneously. All the sampling interval and rate were set with 18~36 seconds and 100Hz respectively . The wave reflection was also expamined in this experiments . Since all the reflection coefficient were less than 4.5% , that the effects of reflection was ignored in this paper.

3. RESULTS AND DISCUSSIONS

One case of the experimental results listed in Table 1 are shown on following figures.Fig.3(a)、(b) are the measuring records of the time series of water surface elevation and horizontal particle velocity on a testing section which the water depth is d=17.4cm , and the measuring point is $\bar{z}$=6.8cm above the bottom. Fig.4 (a)、(b) are the same results at $\bar{z}$ = 15.7cm . It is obviously to see from Fig.4(b) that the part of negative velocity records become straight line . This is because the measuring volume of LDV exposes into air , that the signals drop-out take place as wave trough passing by . In this situation the signals of the above mentioned straight line should be replaced by zero,as we calculate the horizontal velocity and mass transport from LDV measuring rccords.

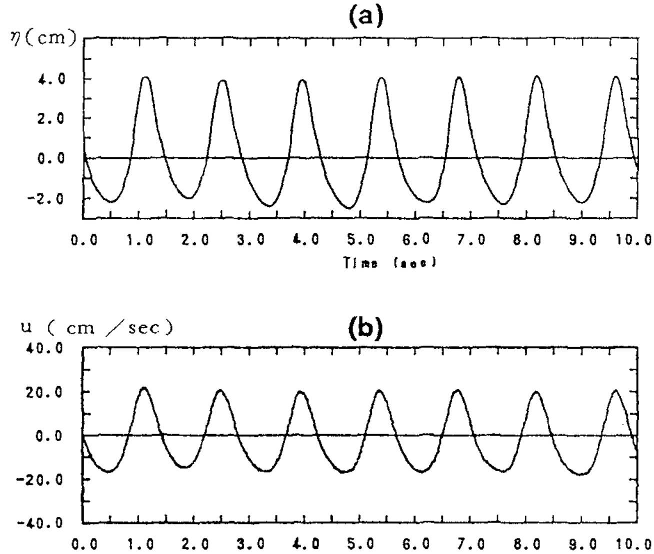


Fig.3 Time series of water surface elevation and horizontal particle velocity at d=17.4 cm and $\bar{z}$=6.8cm for case 1.

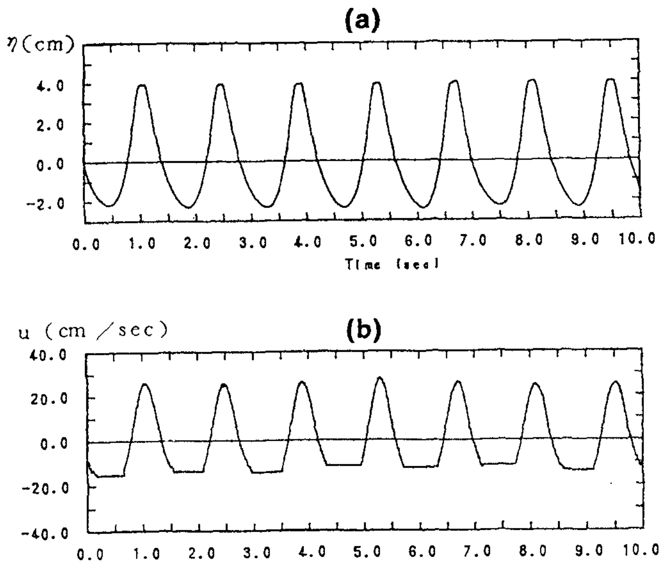


Fig.4 Time series of water surface elevation and horizontal particle velocity at d=17.4 cm and $\bar{z}$=15.7cm for case 1.

After employing the phase average method and then taking average for wave period , the vertical profiles of Eulerian mass transport can be obtained and the results are shown in Fig.5(a) 、(b) 、(c) respectively. Furthermore, the comparison between our experiments and some of the theoretical calculations proposed by Longuet-Higgins(1953), Dalrymple(1976) and Nadaoka et al. (1982) are also made in those figures . From the above results,it is clear to see that the off-shore mass transport takes place inside the region from the proximity of bottom up to wave trough . Around the elevation of wave trough, the mass transport changes its direction to on-shore rapidly,and it reaches the maximun value at still water level , then the mass transport decreases to zero at crest. Further , we can see the magnitudes of on-shore and off-shore mass transport velocity increases in the process of wave shoaling on a sloping bottom. Additional,it is obvious that the theoretical calculations of mass transport from Longuet-Higgins (1953) have more difference with our experiments.As for the results obtained from stream function by Dalrymple(1976),the calculations are coincident with experiments in the region from wave trough to crest.And the results from Nadaoka et al. (1982) are in agreement with our experiments in deep water , but it has more difference in shallow water area.

Fig.6 and Fig.7 show the experimental results of surface profiles and the corresponding horizontal flow fields inside boundary layer at the testing section of d=15.7cm and 9.8cm, respectinely. In above figures , the parameter δ is defined as $\delta=\sqrt{2\nu/\sigma}$ which is the characteristic length scale of boundary layer , ν is kinematic viscosity and σ is angular frequency of wave.From the experimental results inside boundary layer of waves propagating on a sloping bottom,it shows apparently that the flow fields change its direction periodically as wave passed from crest to trough . The on-shore and off-shore flow patterns become asymmetrical gradually , due to the effects of wave shoaling process , and the magnitudes of horizontal particle velocity increases as water depth decreases. Further , the overshooting induced by wave motion taking place near the bottom is also displayed from our experiments.

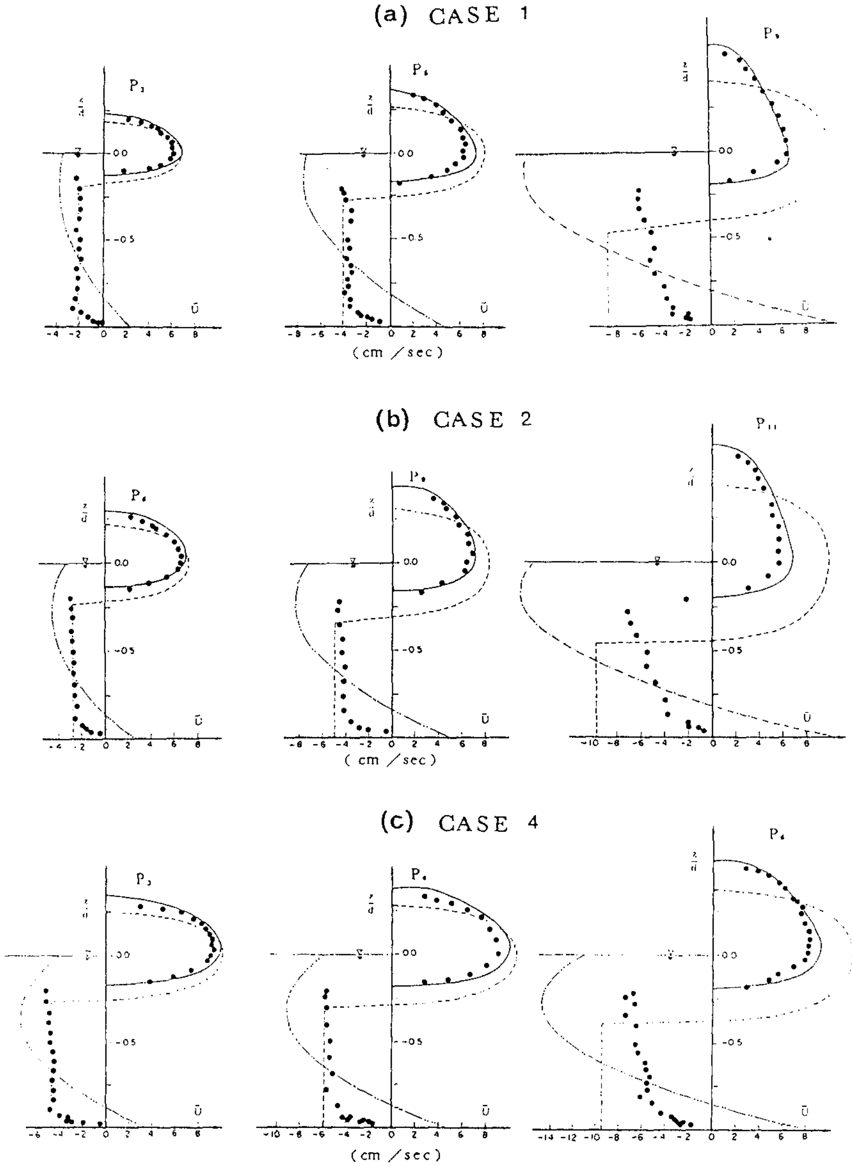
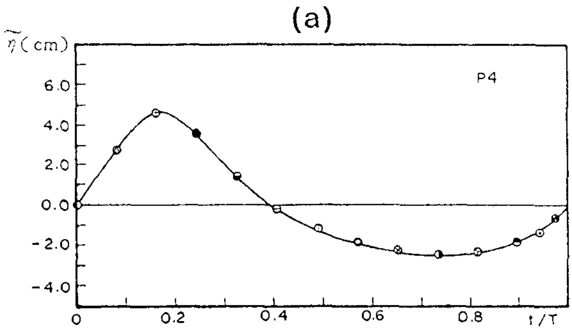


Fig.5 Comparison between experiments and theoretical calculations[● experiments, —·— Longuet-Higgins(1953), —— Dalrymple(1976), - - - Nadaoka(1982)].



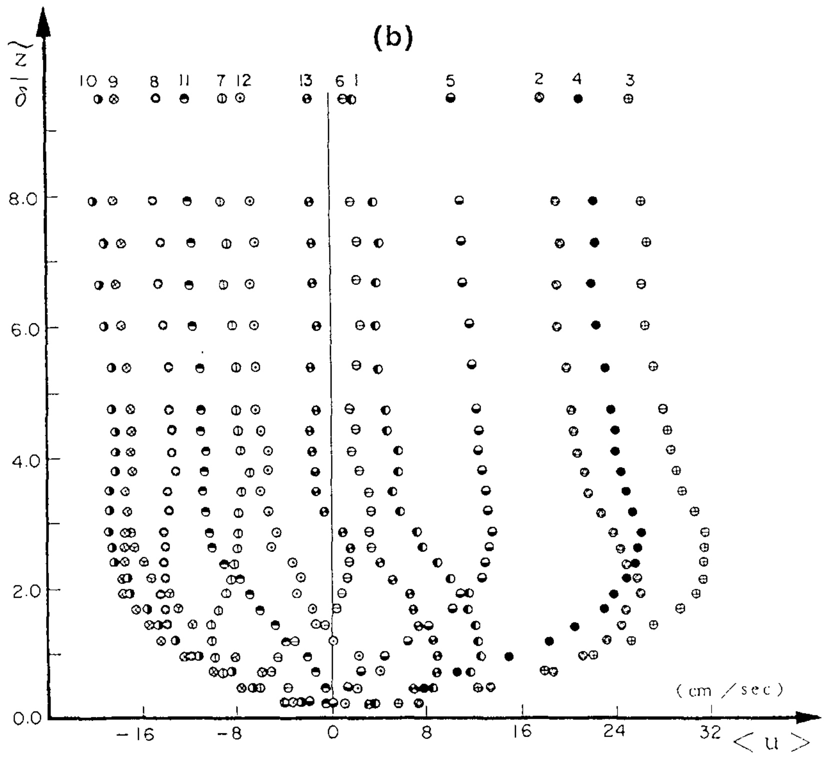


Fig.6 Water surface elevation and horizontal particle velocity inside boundary layer at d=15.7cm for case 2.

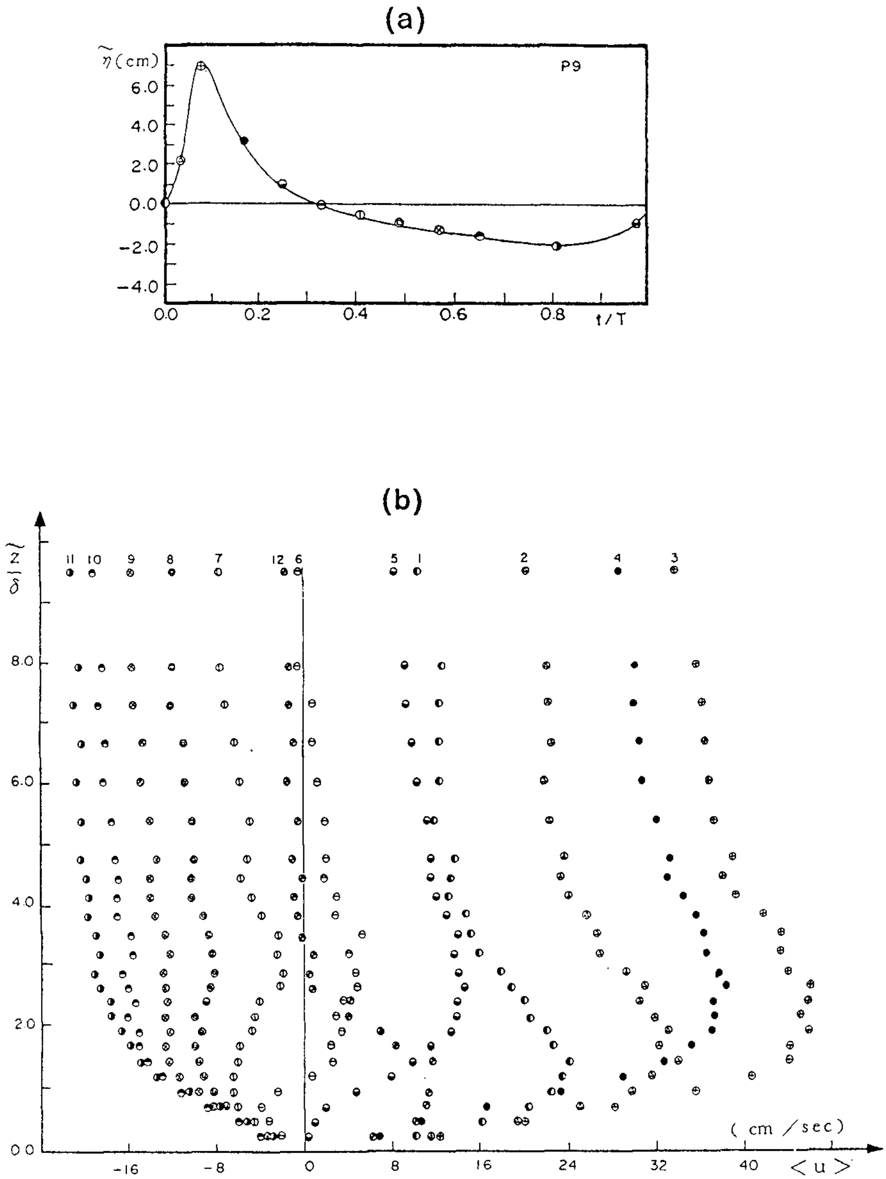


Fig.7 Water surface elevation and horizontal particle velocity inside boundary layer at d=9.8cm for case 2.

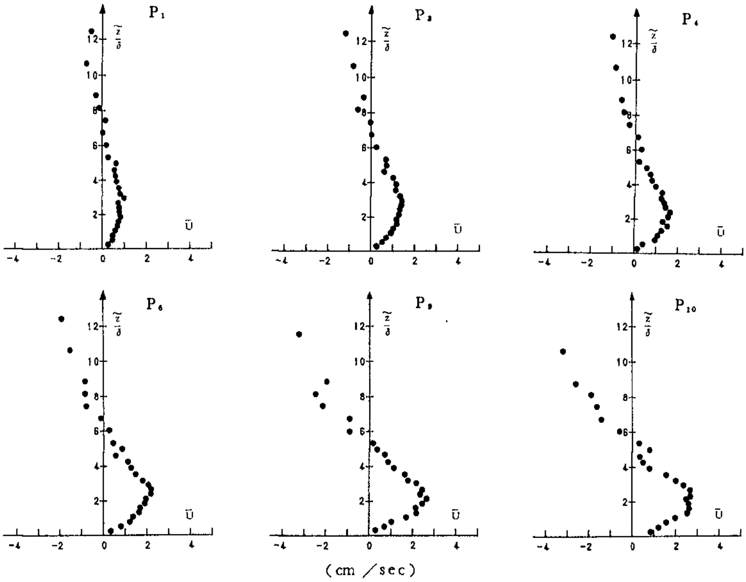


Fig.8 Vertical profiles of Eulerian mass transport inside boundary layer for case 1.

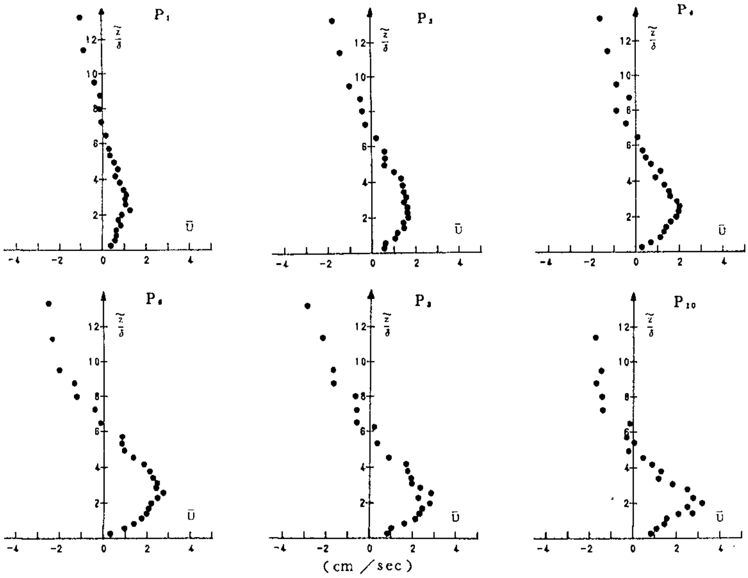


Fig.9 Vertical profiles of Eulerian mass transport inside boundary layer for case 2.

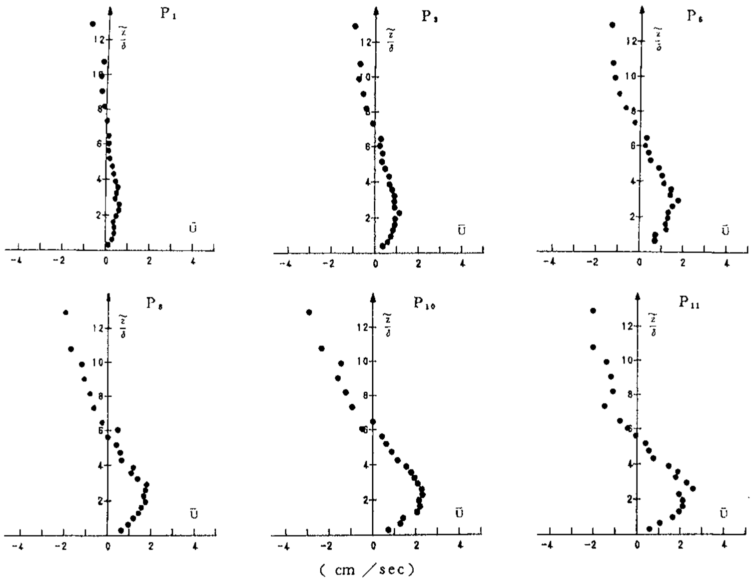


Fig.10 Vertical profiles of Eulerian mass transport inside boundary layer for case 3.

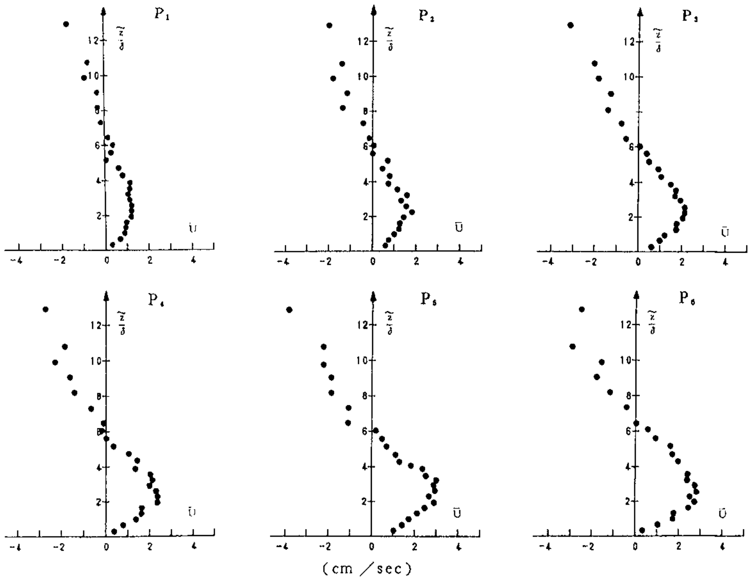


Fig.11 Vertical profiles of Eulerian mass transport inside boundary layer for case 4.

According to all of measuring results, the Eulerian mass transport velocity inside boundary layer are plotted from Fig.8 through Fig.11, respctively. We can see that the vertical profiles of mass transport increase from bottom and reaches the maximun at the dimensionless distance $\bar{z}/\delta=2\sim3$, then decreases gradually to zero at $\bar{z}/\delta = 6.5$. Beyond the above region, Eulerian mass transport becomes negative (off- shore) as the dimensionless distance increasing. Moreover, the similarity profile of Eulerian mass transport velocity inside boundary layer has found from the definition of characteristic velocity proposed by Lin & Hwung(1989),and the result is shown in Fig.12 .Finally, the distribution of the above similarity profile is obtained from regressive analysis and it can be expressed by the combinations of hyperbolic functions as follows:

$$\frac{\bar{u}}{\bar{u}_\infty'}=\begin{cases} 0.21\tanh\left(0.3\,\dfrac{\bar{z}}{\delta}\right)-0.17\tanh^2\left(0.3\,\dfrac{\bar{z}}{\delta}\right) \\ \quad \text{for } 0\leqq\dfrac{\bar{z}}{\delta}\leqq 2.5 \\ -0.087+0.39\,\mathrm{sech}\left(0.3\,\dfrac{\bar{z}}{\delta}\right)-0.25\,\mathrm{sech}^2\left(0.3\,\dfrac{\bar{z}}{\delta}\right) \\ \quad \text{for } 2.5\leqq\dfrac{\bar{z}}{\delta}<6.5 \end{cases}$$

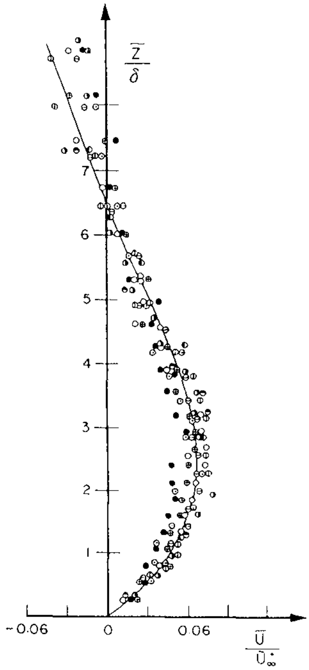


Fig.12 The similarity profile of Eulerian mass transport inside boundary layer.

4. CONCULSIONS

The characteristics of Eulerian mass transpor of waves propagating on a sloping bottom are described in the paper. From the bottom, the magnitude of on-shore mass transport increases gradually and reaches the maximun at the point of $\bar{z}/\delta=2\sim3$, then it decreases to zero at $\bar{z}/\delta=6.5$ .Beyond the above region, the mass transport becomes off-shore up to the elevation of wave trough , then the mass transport velocity changes its direction to on-shore rapidly,and it reaches the maximun value at still water level . After that the mass transport decreases to zero at crest. From the experiments , the similarity profile of mass transport inside boundary layer is also found in this paper.

5. REFERENCES

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