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Experimental study on pollutant movement in surf zone

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Abstract: The experiments on pollutant movement in surf zone were conducted on the two gentle beaches(with slope of 1:100 and 1:40, respectively), for diverse wave cases. The movement contours and direction of pollutants, under the action of regular and random waves with diverse wave amplitudes, were provided and studied in this paper. It was shown that, due to complicated hydrodynamics in surf zone, the pollutant movement state is quite complicated and different from that in pure current zone.

Keywords: surf zone; random wave; regular wave; pollutants

Introduction

Coastal and offshore areas, especially in mild sloping beach, are extremely dynamic regions, where the advection and diffusion of pollutants are more complicated due to the distortion and breaking of wave. And in these areas, the economic activities are highly active and have been influenced directly by the coastal environment. For most developed countries, pollutants have been disposed and drained by pipes into sea far away from coast, and pollutants discharge in shallow water beaches have less been studied. But in most coastal areas of China, pollutants have been drained into sea directly, and thus, some economic loss has been seriously caused. With the development of the coastal economy, pollution would become more and more seriously. As the coastal economy has already been seriously impaired by the deteriorated ocean environment, people have paid more and more attention to it. In the past researches into pollutant movement in the shallow water coast, the influence of wave on it has nearly not been considered, and there are few researches on pollutant movement in shallow water and surf zone. Since the shallow water wave has characters of steep wave amplitude and strong nonlinearity and is extremely turbulent when it approximates breaking, the exchange of substances in it is very active, and transport and diffusion of pollutant in this zone obviously differs from it in pure current zone. In this paper, the experiments of pollutant movement in surf zone were conducted on the two gently beaches(with slope of 1:100 and 1:40, respectively) for diverse wave cases, and the advection and diffusion of pollutants, under the action of regular and irregular waves with diverse wave amplitudes, were provided and studied in this paper.

1 Experimental model

1.1 Experimental equipment

The experiments were performed in the wave basin(with 55 m length, 34 m width and 0.7 m depth) of State Key Laboratory of Coastal and Offshore Engineering at Dalian University of Technology. There was some limit to light brightness around circumstance, and room light was adopted usually when environment was too dark or bright in the experiment. Two beaches, with slope of 1:100 and 1:40 respectively, were adopted, and the slope was rotated at an angle of 30° with respect to wave maker to increase the length of the shoreline. To acquire the clear imagines of pollutant movement, the background of beach was made in white and black grids(1 m × 1 m) were drawn on it, which were also helpful to quantitative analysis. There were two walls and channels(with the width of 3.0 m and the same water depth to that at the front of the beach) on the two sides between the basin and beach, which were helpful to keep the inner water from being disturbed by external water, and the wave dampers were set in the inner of the walls to weaken the reflection and diffraction of wave. The experimental topography can be seen in Fig.1.

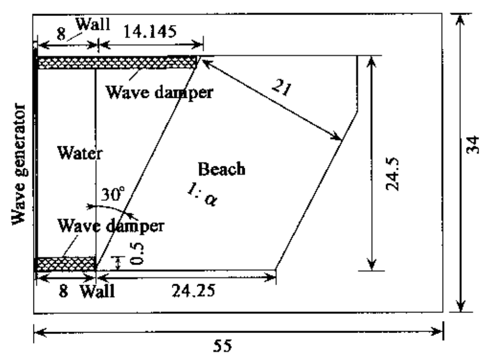

Fig.1 Experimental topography set(unit: m)

Black ink, as pollutant, was transported to surf zone by pipe and drained away in continuous and dot source style.

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The light signal was transformed into video signal by CCD, and then transformed into image file, which could be saved conveniently in computer by image acquisition card DT3155.

1.2 Experimental cases

The incident waves include regular and random waves, and both of them are unilateral. The constant water depth before the slope is 0.18 m for the beach with 1:100 slope and 0.45 m for the beach with 1:40 slope. The experimental conditions for 6 cases are shown in Table 1, and experimental results for these cases are provided in the paper.

Table 1 Experimental conditions

Case	Slope(1:α)	H,cm	Incident wave	θ	A,cm	T,s	D,m	Drainage style
Case 1	1:100	18.0	Regular	30°	3.0	2.0	4.5	Continual
Case 2	1:100	18.0	Regular	30°	7.0	2.0	15.5	Continual
Case 3	1:40	45.0	Random	30°	5.0	1.5	3.0	Continual
Case 4	1:40	45.0	Regular	30°	5.0	1.5	3.0	Continual
Case 5	1:40	45.0	Regular	30°	13.0	1.5	12.5	Continual
Case 6	1:40	45.0	Regular	30°	9.0	2.0	6.5	Dot

Notes: H. water depth before slope; θ. wave angle; A. wave amplitude; T. wave period; D. distance between shoreline and pollutant drainage site. For random wave conditions, H is the average amplitude and T is the average period of incident wave

2 Results and discussion

In shallow water, the pollutants have been mixed quickly and evenly along water depth, and the image acquired and provided in the paper only behaves the general pollutant thickness field along water depth in the experiment. The movement contours of pollutant at different time in surf zone are shown in Fig. 3 to Fig. 8. The exterior curves(Fig. 3 to Fig.8) are pollutant movement contours, and the interior curves are the prime thickness curves, in where the pollutant thickness is the deepest. The reference coordinate used in Fig.3 to Fig.8 is shown in Fig.2, in which wave propagates along negative Y axis and the slope forms a negative 30° angle with X axis.

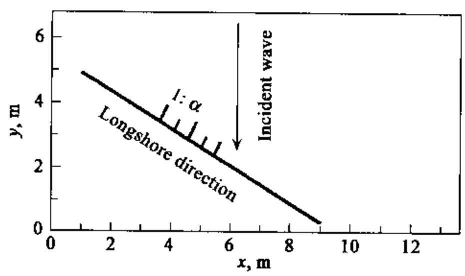

Fig.2 Reference coordinate

In case 1, it can be seen from the pollutant movement contours, that the pollutant movement mainly proceeds along shore and its direction is almost independent of the incident wave propagating direction, which can also be seen from those in case 2. In case 2, the incident wave amplitude is bigger than it in case 1. And it can be seen from Fig. 3 and

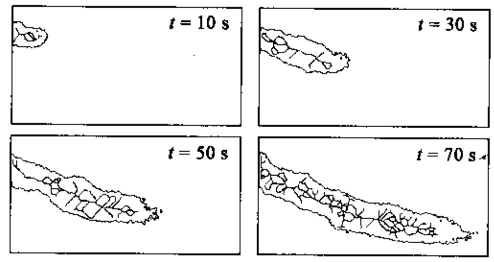

Fig.3 Pollutant movement contours at different time(case 1)

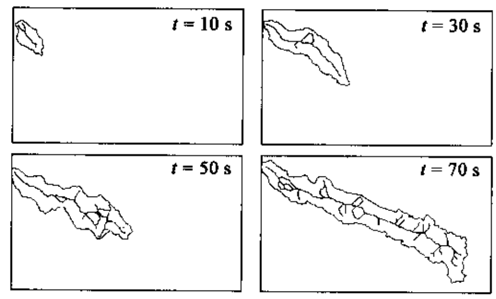

Fig.4 Pollutant movement contours at different time(case 2)

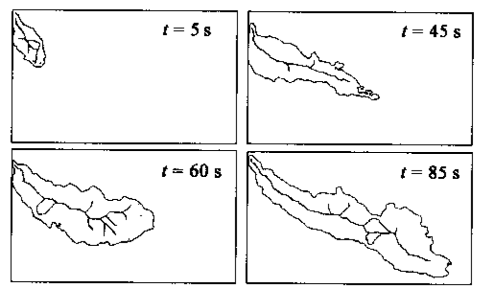

Fig.5 Pollutant movement contours at different time(case 3)

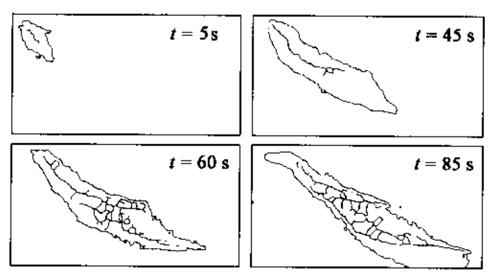

Fig.6 Pollutant movement contours at different time(case 4)

Fig. 4, that the pollutant movement contours in case 2 are some straighter than those in case 1, but the pollutant movement contours and the prime thickness curves in case 1 distribute more widely and evenly than they do in case 2. Consequently, it indicated that the pollutant in case 2 moves more rapidly and turbulently than it does in case 1, and the pollutant in case 1 moves more calmly and its thickness field distributes more evenly than it does in case 2. The same results can also be seen from case 4 and case 5. It indicates that, in surf zone, the pollutant movement mainly proceeds along shore and it moves quickly and turbulently with the increase of the incident wave amplitude. From the pollutant movement contours in case 1, case 2, case 4 and case 5 at different time, it can also be seen that, with the increase of the slope steepness, the pollutant moves more rapidly.

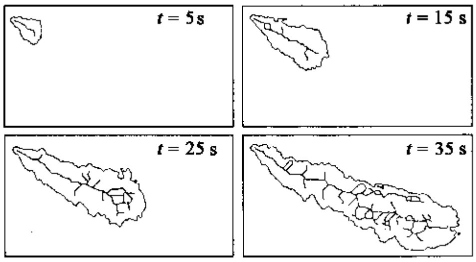

Fig.7 Pollutant movement contours at different time(case 5)

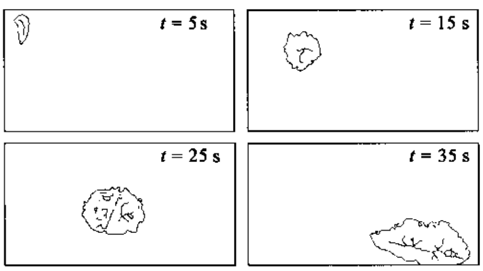

Fig.8 Pollutant movement contours at different time(case 6)

In case 3, the incident wave is random wave. It can be seen from the pollutant movement contours at different time in case 3 and case 4, that the pollutant movement mainly proceeds along shore and pollutant movement in case 3 transforms more turbulent and violent along shore in temporal than it does in case 4. It may be concluded that, the movement of pollutant is more violent and the distribution of pollutant thickness field along shore is more irregular under the action of random incident wave than those under the action of regular incident wave.

In case 6, pollutant was drained away in dot source style. It can be seen from the pollutant movement contours at different time that the movement of pollutant contours and diffusion of pollutant along shore is more obviously and quickly than it in other direction. It indicated that the advection and diffusion of pollutant is mainly proceeds along shore in surf zone.

From the results above, it may be concluded that, in surf zone, pollutant transports and diffuses mainly along beach and its movement direction is almost independent of the incident wave direction; under the action of regular incident wave, pollutant moves more calmly than it does under the action of random incident wave; with the increases of the incident wave amplitude and the steepness of beach slope, the pollutant moves more quickly and turbulently. These may be explained that, as the wave propagates at a oblique angle to the beach, the wave height in surf zone decreases rapidly with distance to shore with the dissipation of wave energy due to wave breaking and bottom effects, this results in strong gradients in the wave radiation stress field and the mean free surface displacement, and they provide driving force for the water in surf zone and a circulation mainly along shore has been driven, which brings the pollutant moves with the current along beach; under the regular incident wave, the driving force is more calm than it under the action of random incident wave and steady current forms, which provides a steady circumstance for pollutant movement; with the increases of incident wave amplitude and steepness of beach slope, the driving force and bottom friction increases and the stronger current is induced, which brings pollutant moves more quickly and the movement of pollutant in it becomes more turbulently. Due to the quite complex hydrodynamics, the pollutant movement in surf zone is quite complicated and different from that in pure current zone.

3 Conclusions

In this paper, experimental study on pollutant movement in surf zone on two gently sloping beaches has been conducted, and movement contours of pollutant under the action of diverse incident wave cases in surf zone have also been provided and studied. Since the brightness of environmental background for image acquisition was frequently affected by the circumstance, and the image contrast always was inflected with it, which brought some great trouble for quantitative analysis of pollutant thickness field and only the qualitative analysis of pollutant movement was made in the paper. For the future research, these can be overcome under the steady circumstance and quantitative analysis may have been made, which is promising for the research into hydrodynamics and pollutant movement in surf zone.

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