3-D PARTICLE METHOD FOR SIMULATION OF FLOW OVER STEPPED CHANNEL

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A flooding to an urban underground space may cause the serious damage on a life of human, because it passes the staircase that is the refuge route from the underground space. Hence, in order to save a life of human, it becomes necessary to study the hydrodynamic characteristics of flow in the staircase. All the previous studies are executed in the experimental way, and numerical simulation has not applied yet. It is because that the existence of air pocket, which is formed at back of the convex corner of steps, and resultant complicated behavior of water surface in a stepped channel make it difficult to analyze based on the ordinary Eulerian techniques as the VOF method. However, the particle method is suitable for analyzing a rapidly changing flow, because it is the Lagrangian technique tracking a moving particle as a definition point of physical properties. In this study, the MPS method, which is proposed by Koshizuka and Oka(1996), is expanded to the 3D field. The stream on stepped channel, the computational domain of which is comparatively small, is reproduced by the 3D MPS method.

According to Ohtsu and Yasuda(1997), stream over staircase is categorized into three conditions; i) skimming flow, which occurs in a steep-slope channel under the comparatively large discharge, ii) nappe flow, which occurs in a mild-slope channel under the comparatively small discharge, and iii) transition flow, which is the transition region of two flows.

An example of calculated result of the skimming flow is shown in Figs. 1 and 2. Air pocket cannot be seen in the concave corner of stairs at all. Moreover, the velocity in the concave corner of stairs is almost less than 10% of the mainstream, and dead water region is formed. Because all these calculations are executed using the single-phase flow model, the pressure change of the gas phase in air pocket cannot be treated. Therefore, it cannot be said that air pocket in a strict meaning was reproduced, however the enclosed region, in which water particles do not exist, is defined as air pocket. It can be seen that the flow remarkably circulates in the concave corner of stairs, and the mainstream flows in almost the parallel direction to the virtual bed which is the line linking convex edges of stairs. These characteristics show the same tendency as the experimental result.

Figs. 3 and 4 show an example of calculated result of the nappe flow. The mainstream flows down like a dropping jet with repeating collision and repulsion with steps of stair. Air pockets are formed at the back of the steps and exist stably through a total computation process. In the concave corner of stairs, a dead water region is formed just like the skimming flow. These characteristics of the calculated result show a similar tendency with characteristics of flow which were observed in the previous experiments.

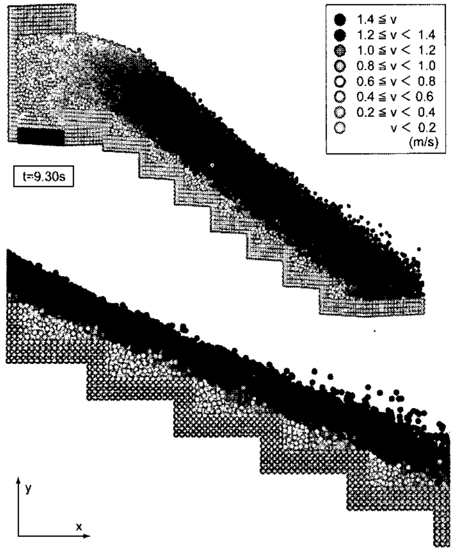

Fig. 1 Skimming flow

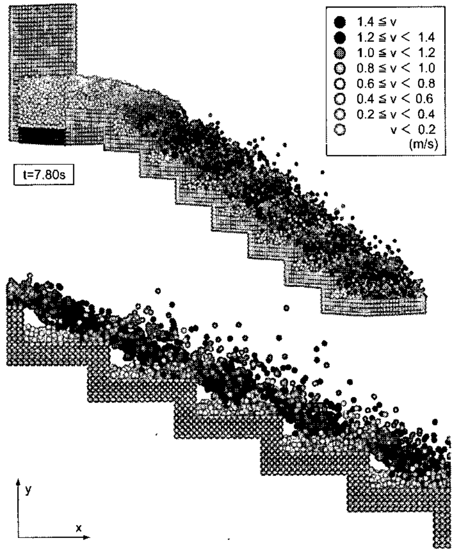

Fig. 3 Nappe flow

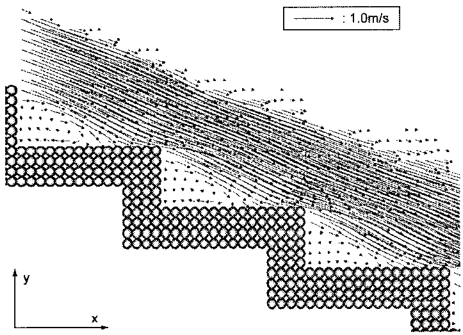

Fig. 2 Velocity vector (skimming flow)

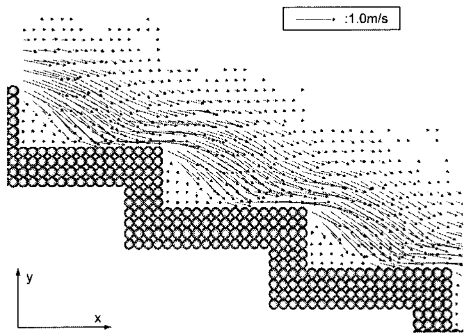

Fig. 4 Velocity vector (nappe flow)

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