(Ⅱ −48) LOCAL SCOUR DOWNSTREAM OF A SLUICE GATE

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INTRODUCTION

Scour is a natural phenomenon caused by the flow of water in rivers and streams. Scour occurs naturally as a part of the morphological changes of rivers and as a result of man-made structures. The safety of aprons downstream of sluices and of energy dissipating devices can also be threatened by the erosion of sediments in their vicinity. At present, this is also a problem of hydraulic structures in Mekong Delta where the aprons and their bed protection downstream of hydraulic structures, because of some reasons, don't have enough length for submerged jump and eventually the scour holes formed behind the aprons. On tidally-affected lowlands where there is always submerged jump on aprons and submergence factor changes progressively according to the tidal elevation, the foundation is weak soils as mud, fine sand..., the prevention of scour is almost impossible. The decay of maximum velocity for a submerged jump is slower than for a free jump and the proportion of jump length to submergence factor is linear (Rajaratnam and Wu, 1995). So that, an apron for submerged jump is often uneconomic. This paper will define the relation between the apron length and the dimensions of scour hole. This is an indispensable information for designing an optimal apron and bed protection downstream of hydraulic structures.
The problem of scour is an extremely complex one since the flow conditons inclusive of turbulence within the scour hole are difficult to evaluate. Even when this is possible, the interaction between the sediments and the flow properties is not easily quantified. Thus, theoretical analysis of local scour is in a rudimentary stage, and so far prediction of the extent of scour is mostly based on the empirical results. In this paper, the experiments have been performed in a horizontal plexiglass flume, 20 cm wide, 50 cm high and 1000 cm long. The bed of fine sand is 10.54 cm thick; nearly uniform size of sand of 0.225 mm has been used. The flow direction was observed by moving of particles which were illuminated with an continuous argon-ion laser in a sheet along the vertical centre-plane of the channel, the particle images were recorded with a video camera system. On the whole, 11 experiments were made on the scour profile and 21 experiments were made on L_{cr}, with Froude number varying from 3.189 - 7.39, submergence factor was varied from -0.172 - 4.236.

FLOW REGIMES AND SCOUR PROCESS

At a certain hydraulic condition, the flow regime and the scour process depend on the length of apron. There are three main flow regimes of the flow passing over the apron, namely:

1. <u>A-jump</u>: $L > L_{cr}$, so far as the A-jump is concerned, if a significant portion of its length is located in the apron itself, the scour formed behind the jump (Fig. 1-A). This scour has been extensively studied. The scour is mainly caused by the turbulence energy, the bed material is picked up by the rotating ascending current in the vortex with a vertical axis and is thrown out sideways. There are four phases of the scour process: <u>Initial phase</u>, this phase is characterized as the development of scour is very fast. During this phase, a certain amount of bed material near the upstream scour slope goes into suspension, most of these suspended particles are convected with the main flow and remain in suspension because of the internal balance between the upward diffusive flux and the convective flux, some of these particles will deposit and go into suspension again because of the large bursts of turbulent flow near the bed. <u>Development phase</u>, the scour depth increases considerably, but the shape of the scour hole remains the same. In the recirculation zone the suspended load close to the bed has decreased significantly. <u>Stabilization phase</u>, the rate of development of the maximum scour depth decreases compared with the erosion capacity downstream of

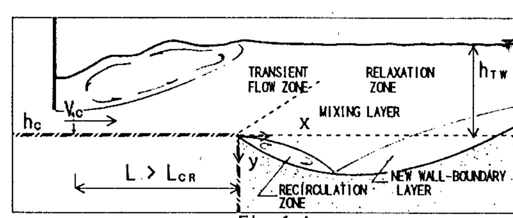

Fig. 1-A

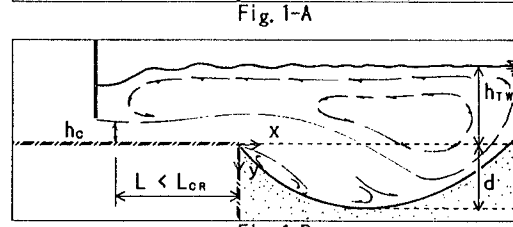

Fig. 1-B

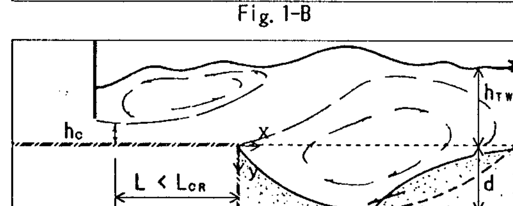

Fig. 1-C

the point of reattachment, so that the dimensions of the scour hole increase more in the streamwise direction than in the vertical direction. Equilibrium phase, the dimensions of the scour hole no longer change significantly.

2a. **Plunging jump**: $L < L_{cr}$, reducing the apron length L from A-jump regime, at a length L_{cr}, the supercritical flow dispersion is unfinished in the apron, the main flow from the apron plunges to the bottom of the scour hole and causes severe scour with similar state of B-jump regime (Fig. 1-B). This regime is characterized by the formation of a substantial surface eddy and the flat surface.

2b. **Wave jump**: $L < L_{cr}$, as long as the dimensions of the scour hole develop over critical dimensions, the main flow from the apron moves upward, flows along the surface and undulations propagate far downstream (Fig. 1-C). This regime is characterized by the formation of two large eddies, one on the jump and one in the scour hole. During this phase the scour hole is filled gradually by the convective flux transported bed load from downstream. Whenever the dimensions of the scour are insufficient to produce wave jump, the plunging jump repeats itself. Eventually the dimensions of the scour hole increase gradually in the streamwise direction, while both the upstream scour slope and the maximum scour depth is almost unchanged (Fig. 3).

Critical apron length:

$$L_{cr} / h_c = (S + 8 F_r^{-0.7}) / (1.4 F_r^{-1.7}) \quad (1)$$

Where $F_r = V_c / (g h_c)^{1/2}$: Froude number,

$S = h_{tw} / h_2 - 1$: Submergence factor,

h_2 : Subcritical sequent depth of h_c.

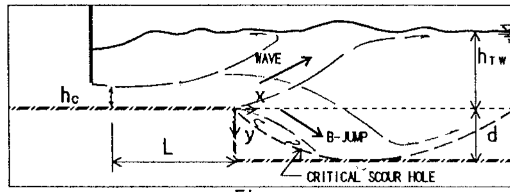

Fig. 2

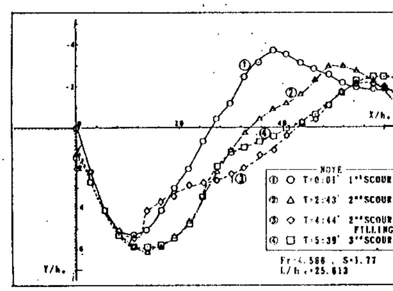

Fig. 3: DEVELOPMENT OF SCOUR PROFILES AS TIME PROGRESSED

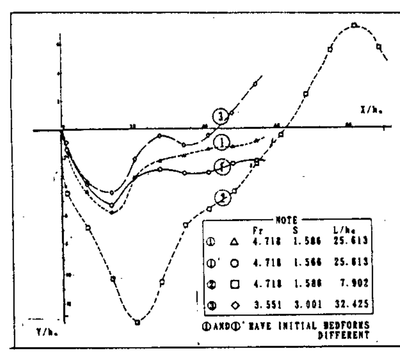

Fig. 4: DIMENSIONLESS SCOUR PROFILE

CRITICAL SCOUR HOLE

Regarding the scour formed by plunging jump and wave jump, the dimensions of scour are very sensitive to experimental conditions (Fig. 4), so that determination of a unique scour hole profile is impossible. The scour hole formed just after the first plunging jump is named as a critical scour hole, it has a minimum section.

1. **Scour depth**: The maximum scour hole d has the same value as the case of the wave formed from the B-jump at an abrupt drop (Fig. 2):

$$d / h_c = \frac{\{ S - [0.2678 - 0.5404 \log_n(F_r) + (0.1281 - 0.0607 \log_n(F_r)) L / h_c] \}}{\{ 0.1347 - 0.0462 \log_n(F_r) + (0.0211 - 0.0096 \log_n(F_r)) L / h_c \}} \quad (2)$$

2. **Scour profile**: In the experimental conditions as mentioned before, the following equation for scour profile is obtained:

$$y = - 0.195 x^2 / d + 0.882 x \qquad \text{for} \quad x < 3.4 d \quad (3)$$

For $x > 3.4 d$ the downstream scour slope is flatter.

CONCLUSIONS

1. The flow passing over the rigid apron with a short length is similar to a hydraulic jump at an abrupt drop.
2. The scour-deposition process is periodically repeated according to the flow regime, plunging jump or wave jump. This process can be stopped by forming a man-made scour hole and by preventing of bed load to fill the scour hole again, eventually there is only the wave jump on the scour hole and the aprons will be protected more safely.
3. The scour profile in the case of wave jump and plunging jump is roughly similar to the scour profile formed behind A-jump (Hassan and Narayanan, 1985).

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