AN EXPERIMENTAL STUDY OF BANK TOE SCOURING IN BANK-PROTECTION WORKS

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Scouring in bank toe is the main factor that resulted in destroying in bank- protection works. In this paper, part of bank-protection works in ChangJiang River was taken as prototype. Through simplified physical experiments in fixed bed and movable bed, the flow characteristics in bank toe and mechanisms of bank toe scouring for several types of common bank-protection works were investigated.

Bank-protection works can be summarized into three types according to their characteristics. (1) Rigid bank-protection. This mainly includes concrete bag, cement-rubble etc. (2) Flexible bank-protection. This mainly includes reinforced concrete hinge raft, sand bags raft, etc. (3) Scattered-granule bank protection. This includes rock riprap, sand bag, etc.

In the experiment the emphasis was put on the part of the bank toe and locally simplified model was applied. The bank toe had larger dimension than others. By doing so, the flow velocity including time-average and fluctuating velocities were measured in detail. From the point of the flow structure and the variation of velocity the main factor that caused bank toe scouring was analyzed. On the basis of this analysis, locally simplified movable-bed model was adopted to investigate the variation process of flow pattern and sediment erosion. The characteristics of bank toe scouring in three different types of bank-protection works were investigated.

For rigid bank-protection, it can be seen from the experiment that when scouring hasn't occur in the riverbed except for bank-protection, after the bed has been scoured to a certain depth, local scouring began in the lower part of the bank toe and then lateral caving occurred. At the same time flood happened and caving expanded to horizontal, vertical and lateral gradually. The scour hole was crescent shaped. It expanded to the boundary of the model and then extended to the downstream.

Under the bank toe where the length of scouring section was longer the longitudinal flow velocity indicated that the velocity reduced gradually in the direction of vertical to bank. But the amplitude of reducing was not great.

It indicated that after scouring occurred under the bank toe, the decrease of velocity in the lower part of bank toe was not remarkable. The lowest relative velocity kept about 0.75. In this case, scouring in bank toe developed continuously.

The data of flow field showed that longitudinal velocity of intruding flow decreased. Flow pattern was turbulent. However, lateral velocity occurred locally and the velocity fluctuation intensity increased remarkably. The pressure varied due to remarkable increase of the velocity fluctuation. Thus a series of eddies with different scales formed. These eddies formed, developed, joined and then broke. A series of phenomena such as 'abrupt flow' occurred. These flow patterns contributed to sediment pick-up and scouring in the bank toe.

In the range of between bank toe and the point that is 0.2 times water depth from the bank toe the characteristics of velocity were remarkably different from that in the far field. The velocity fluctuation was remarkable greater than that in the far field. When the riverbed was scoured but the bank toe hasn't been undercut, the maximal velocity fluctuation was in the point that is 0.15H from the bank toe. When the bank toe was scoured remarkably by flow, the point with the maximal velocity fluctuation intensity was about 0.1H from the bank toe. The maximal relative variation amplitude reached to about 1.928. It indicated that scouring in the lower part of the bank-protection would continuously develop.

In the outer edge of the scattered-granule bank-protection, local velocity around the dumped-rock increased due to circumfluence. At the same time, unsteady flow pattern such as spiral flow and backflow occurred. The fluctuation of velocity increased.

The time-average velocity and velocity fluctuation increased. Sediment in the area facing to the flow was easy to be scoured due to strong fluctuating velocity. The loss of sediment would result in the rolling of rock to the outside of the bank-protection. With this the dumped-rocks in the bank slope rolled off. The stability of bank-protection would be destroyed.

After the bank toe has been scoured locally, the flow pattern in the lower part of the bank toe and the velocity distribution in plane were similar with that of rigid bank-protection.

According to the experiment of movable-bed model, in the same working condition, the scouring in bank toe was most serious in rigid bank-protection and most slight in scattered-granule bank-protection and moderate in flexible bank- protection.

From the point of protecting bank toe, rigid bank-protection was the worst. Flexible bank-protection was better than rigid bank-protection. The scattered-granule bank-protection was comparatively good in the condition that dumped-rock was sufficient. In three kinds of bank-protection, the flow turbulence near bank toe was enhanced and the tendency of scouring in bank toe took place. In practical protection engineering, in order to keep bank-protection stable efficient measures to fix bank toe should be taken and maintenance should be done in time.

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