CHAPTER-I

INTRODUCTION

1.1 GENERAL

Most of the hydraulic structures are constructed over erodible bed, which causes an abrupt change in the flow field and thereby causing the aggradation or the degradation of the river bed. A few typical examples of such structures are (i) dams, barrages and weirs; (ii) spillways, sluices and culverts ; (iii) river training structures ; (iv) bridge piers etc. Many investigators have studied the flow characteristics and local scour downstream of such structures. The primary interest of such study is the determination of probable maximum scour depth and the scour pattern below the concerned structure. Still there is a great deal of partical interest in such studies for the safety and economic design of the structure.

1.2 LOCAL SCOUR AND RELATED PROBLEMS

Water is usually discharged at a relatively high velocity through the structures as mentioned above. This in turn exerts high local shear stress, over the river bed, exceeding the critical shear stress value for the incipient motion of the river bed material and thereby causing the degradation of the river bed at the downstream of the concerned structure. This will result an increase in the local flow depth and consequently the shear stress acting over the bed will be reduced, which in turn will cause a reduction of the scouring rate. The stream, therefore, is in the process of adjustment due to the increase of the scour hole with the continuous removal of bed material. The limiting extent of scour is reached when the shear stress acting over the bed is reduced to the critical shear stress value for the bed material. This limit reaches asymptotically with time. Therfore, the shape and the extent of scour hole is very much dependent on time. Initially, the scour development with time is very rapid which slows down in the later phase and the time required to achieve the state of equilibrium is very long which cannot be attained in case of a natural river. However, depending on the shape and the extent of the scour hole and the soil mechanical properties of the bed material, the hydaulic structure may collapse while passing very high discharge through it. It is, therefore, necessary to study the whole process of scour phenomena, besides the probable maximum scour depth. Apart from above considerations, it is also of interest to know the sediment transport rate so as to formulate suitable scale modelling laws.

The phenomenon of local scour around a structure is very complicated due to the variation of the three dimensional flow field. The sediment characteristics, the nature of the obstruction and the type of flow has pronounced effect on the development of scour hole. It is, therefore, impossible to have a unique anlytical solution for the problem. Some mathematical models, however, have been produced through the analytical treatments, but those are either over simplified or restricted to some simple cases. Hence, the attempts require to be confined mainly in the experimental investigation of such problems.

There is urgent need for practical solutions of the problems relating to local scour and deposition since they constitute the most important part in the design and maintenance of hydraulic structures. Unfortunately, the local scour phenomena cannot satisfactorily be studied in the field or with the full-size structures, due to the difficulties in controlling the numerous variables describing the flow situations. Even assuming that such an investigation is possible, the results would be restricted to the particular case, studied. Thus, in order to have a better insight to the problem and to identify the several parameters influencing the flow situations, it is necessary to carry out experimental investigations with small scale models in the laboratory.

1.3 STUDIES ON SCOUR DUE TO JET

In context with the generalised scour studies, the scour caused by a jet is of special interest, since such an investigation permits the intial flow situations to be described accurately and thus permitting the basic variables to be studied systematically. The flow characteristics and the local scour due to different types of jets e.g., circular jets (horizontal, inclined or vertical); horizontal wall jets etc. have already been studied by many investigators.

The flow characteristics of the classical wall jet, i.e., the plane turbulent wall jet issuing into the same stationary fluid of semi-infinite extent was first experimentally investigated by Forthmann (1936). Albertson et.al. (1950) carried out the classical study of the diffusion of a free two dimensional jet issuing out of a slot, into the surrounding fluid. The analytical solution of the problem of wall jet whether radial or plane , laminar or turbulent was investigated by Glauert (1956). Schwarz and Cosart (1961) carried out the study of turbulent plane wall jet both analytically and experimentally. The flow characteristics of the submerged hydraulic jump was investigated by Rajaratnam (1965), cosidering it to be the case of a plane turbulent wall jet. Chatterjee and Ghosh (1980) studied the flow characteristics due to a two dimensional submerged horizontal jet issuing from a sluice and flowing over a rigid apron and then on to an erodible bed.

Rouse (1939) did the pioneering investigation of the scour of a bed with noncohesive sediment by a vertcal jet of clear water. The study of the scour of a flat sand bed due to a two dimensional horizontal jet of water was carried out by Laursen (1952). Dodiah et.al. (1953) investigated the scour of a gravel bed below free overfall, due to vertical solid and hollow jets. Based on the experimental data of localized scour resulting from different types of flow obstructions, Carstens (1966) formulated the sediment transport functions. Local erosion of a horizontal bed due to an inclined jet, drowned in a relatively large depth of water, was studied by Francis and Ghosh (1974). Rajaratnam and Macdougall (1983) investigated the erosion by plane horizontal wall jets with minimum tailwater. Chatterjee, Ghosh and Chatterjee (1994) studied the local scour and sediment transport due to a two dimensional submerged horizontal jet issuing from a sluice and flowing over a rigid apron and then on to an erodible bed.

The investigations carried out by the above mentioned authors, however, have the special relevance to the present study. The outcome of those investigations are discussed in details, alongwith the review of other relevant studies in Chapter -II.

1.4 ABOUT THE PRESENT STUDY

The investigator has undertaken an experimental study of the flow characteristics and the local scour due to a jet of water issuing out of a sluice gate and flowing over a rigid apron and then on to an erodible bed, with shallow tailwater. To the best of the writer's knowledge neither the flow characteristics nor the scour phenomena (alongwith the formulation of sediment transport function) for such a jet situation, has been reported earlier by any investigator.

In the present study, the investigator has attempted to find the flow characteristics of the problem considering it to be a two dimensional turbulent wall jet in shallow tailwater. However, the classical wall jet solution as proposed by other authors could not be directly applied in this study. This is because of the introduction of the erodible bed preceded by a rigid apron of a finite length, which alter significantly the flow characristics of the jet. On a closer scruitiny of the velocity profiles for such a jet, it is observed that there exist distinctly two different layers - one inner layer (Close to the boundary) affected by the presence of the boundary and the other outer layer unaffected by the bounday. Hence, the writer has studied the diffusion characteristics of such a jet following the procedure of Albertson et.al. (1950) and the equations governing the diffusion process have been formulated and compared with that of a free jet. The flow characteristics inside the boundary layer, on the other hand, have been studied proceeding with Vón Kármán integral equation. Based on the experimental findings, the velocity distribution law within the boundary layer and the expression for the growth of its thickness with distance for the rigid apron as well as for the erodible bed have been derived. From the derived velocity distribution law at the location of maximum scour, an expression for the critical shear stress has been obtained with the solution of the intergral equation, and an expression for the pressure-shear relationship for a Preston tube has been developed. Assuming similar nature of the velocity profiles during the scour process, the pressure drop has been measured by using the Preston tube at suitable time intervals during the development of scour hole. With the help of values of shear stress obtained from the recorded dynamic pressure drops, an expression for the time variation of shear stress at the location of maximum scour has been developed.

Apart from the study of the flow characteristics as mentioned above, detailed investigation of the scour process also has been undertaken. Using the experimental data, the writer has developed expressions for computing the time required to reach the maximum scour depth, development of the scour hole as a function of time and the location of maximum sour. Thereafter, the relationship for computing maximum scour depth as a function of time has been developed correlating the efflux thickness and velocity of jet, the length of the rigid apron,the tailwater depth and the representative grain diameter of the erodible bed. Moreover, the maximum scour depth at the state of equilibrium, has been expressed as a function of efflux Froude number and the representative grain diameter. It has been studied that the nature of the scour profiles as obtained at different time intervals during the development of scour hole, is similar. The equation for the valume rate of sediment trasport has been expressed as a function of the flow parameters , characteristics of bed material and time. A generalised transport equation correlating the weight rate of transport to the fluid power of the jet and the transport stage has been formulated after Bagnold (1973); the parameter "transport stage" being analogous to the " sediment number " after Carstens (1966).