ABSTRACT

Scour is the process or result of erosion due to flooding water, excavating and carrying away material from the bed, banks of stream and from the surrounding of any structure like bridge pier or abutments present in flowing water. The mechanism of flow around a pier structure is so complicated that, it is difficult to establish a general empirical model to provide accurate estimation for scour. But under-prediction of scour depth can lead to costly bridge failures, while over-prediction can result in unnecessary construction costs. Therefore, the knowledge of the anticipated maximum scour depth is essential for a proper design of the foundation of the bridge piers.

Local scour i.e. removal of bed materials around a bridge pier is a problem of great concern to hydraulic engineers. This complex phenomenon resulting from the interaction of the three-dimensional turbulent flow field around the cylinder and the mobile channel bed. Local scour around bridge piers have resulted in more bridge failures than all other causes in recent history. The scour prediction methods developed in the laboratories and the scour equations based on laboratory data did not always produce reasonable results for field conditions, because laboratory investigations often oversimplify or ignore many of the complexities of the flow fields around the bridge piers. The physical scales, the fluid properties and the boundary conditions in the small-scale models should be derived from the large-scale prototype according to the Hydraulic Similitude Laws. Geometric similarity is usually required for all models, Reynolds number similarity for models involving flow around bodies and Froude number similarity for models involving free-surface flows. In fact, it is not practical for
a physical model of local scour around a bridge pier to satisfy all these similarities. However, unlike a physical model, which suffers from scale effects, the computational fluid dynamics (CFD) model employs the actual dimensions and operating conditions to calculate turbulent velocity and sediment scour.

Attempts are made in the study to determine the scour depth by a series of laboratory model tests. For that purpose various flow conditions and pier configurations were considered. The experiments were conducted in a straight channel of rectangular cross-section. The pier geometry in terms of perimeter was kept constant in all experiments. Both single and double piers were studied. In general, for piers that were not skewed with respect to the flow, the location of maximum scour was found in the immediate vicinity of the upstream nose of the pier as expected.

This research provides a means of assessing some important aspects of scouring process and various factors that influence the scour depth. The program of work performed in this study includes the following:

(i) Local scour at cylindrical bridge piers in both uniform and non-uniform cohesionless sediments was investigated experimentally. The aim of the study was to improve understanding of local scour around bridge piers with sediment transport. Four empirical equations which relate the equilibrium depth of scour with approach velocity, flow depth and sediment size were obtained for uniform and non-uniform sediments.

(ii) Experiments were conducted to study the scouring effect for different shapes of pier and scouring behaviour for different shapes under different flow conditions.
(iii) The effect of pier spacing on scour depth was also considered. Scour pattern due to interactions of piers in straight channels is considered. This reveals that the main abrupt change in channel bed and banks is because of scour hole formation.

(iv) Experiments were conducted to study the impact of suspended sediments on equilibrium local scour depth and observed in reduction of scour depth due to suspended sediment. Reduced bed shear stress is one possible explanation for the observed reduction in local scour depths.

(v) Experiments were conducted under dynamic equilibrium conditions where there was continuous sediment input from upstream of the scour hole such that at equilibrium, the amount of sediment entering the bridge site is equal to that leaving. Both the effects of armouring and sediment size diminish for increasing velocity. At high velocity where all the sediment particles are mobile, the non-uniform sediment behaves like uniform sediment.

(vi) Maximum scour depth calculated by using the proposed formula (for circular pier) and Lacey-Inglis formula (as recommended by Indian Road Congress 1998 & 2000 for finding depth of scour below highest flood level in natural channels flowing in alluvium) were compared and analyzed the differences of the results with observed value in field. The study shows that the proposed formulae appear to give a reasonable estimate of the local scour depth. While the Lacey-Inglis formulae appear to over predict the scour depth. The difference is attributed to the fact that Lacey-Inglis equation is based on limited data, which do not represent the real situation in the field.

(vii) Study was conducted on adaptability of equation derived from small scale laboratory experiments and observed that Reynolds number would provide useful
information for adequately adopted equations which were derived from small scale laboratory experiments and applied to large bridge piers in field applications.

(viii) Investigations on scour depth development has been done through various experiments. Experimental relationships may be inadequate because of the large number of parameters affecting scour. The depth of local scour is a function of a number of different parameters, many of which are interrelated. So, in this study, Artificial Neural Network (ANN) models were used to check the consistency of the experimental data and thus validate the experimental results.

From the model study as well as from the analysis of the results the findings can be summarised as : (1) maximum scour is observed around the pier than in the other locations of the channel (2) intensity of scour was more in the upstream adjacent side of pier (3) stream-lined bodies, such as Double-D shape pier and circular pier, was found more effective in reducing depth of scour (4) for a very fine sediment bed ($D_{50}=0.1\text{mm}$), the live bed scour is more prominent than the local scour (5) with reduction in spacing between the piers, the scour depth was increased due to the interaction of vortices created around the piers (6) scour depth was maximum under clear water flow and observed that depth of scour hole reduces with increase of suspended fine sediment on approaching flow (7) although the scour process continues for long time, but a practical equilibrium was reached within a relatively short time and after which the increase in the depth and extent of scour becomes virtually imperceptible (8) numerical model for circular pier has been satisfactorily validated with field data and also supported by the model derived from the Artificial Neural Network Analysis.