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Scour around a bridge pier - A Review

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Abstract - Scour is a natural phenomenon of removal of bed material due to action of flowing water which ultimately removes sediment around or near the structure; exposes foundation of a bridge pier located in flowing stream and may result in collapse hence prediction of maximum scour depth is important aspect for design of bridge pier. The various parameters and methods as well as relations were proposed by previous researchers. The extensive study of research paper is carried out for a review paper which determines the depth of scour that can be used while designing bridge pier.

Keywords – Scour, Bridge pier, Scour depth, Nonuniform sediment, River bed.

I. INTRODUCTION

Local scour at the bridge pier is the main reason for the collapse of bridge pier founded in alluvial sediments (Melville and Coleman 2000). This process involves two complexities, the three-dimensional flow pattern and the sediment transport. The determination of the scour characteristic is the main topic of interest for the hydraulic engineers. By underestimation of scour depth, it will result in exposure of foundation and ultimately lead to endangering safety of the structure. By overestimation of scour depth, it will lead to uneconomical design.

II. LITERATURE REVIEW

Several relationships for the temporal advance of scour depth either at a pier, an abutment, or at spur dikes were proposed by Ettema (1980), Yanmaz and Altinbilek (1991), Melville and Chiew (1999), or Cardoso and Bettess (1999). The significance of the temporal scour evolution rather than the equilibrium scour depth was emphasized by Oliveto and Hager (2002, 2005), Chang et al. (2004), Sheppard et al. (2004), Mia and Nago (2003), Kothyari and Ranga Raju (2001), Ahmed and Rajaratnam (2000), Melville and Coleman (2000), Cardoso and Bettess (1999) and Kothyari et al. (1992a,b).

Kothyari at el.(1992b) studied the of temporal variation of scour depth in different flow conditions with different bed sediments are considered viz. uniform, non-uniform, and stratified beds under steady and unsteady clear water flows. The primary vortex in front of the pier has been considered the prime agent causing scour and the mathematical scheme is developed for the computation of temporal variation of scour depth in uniform sediments with steady flows. This research paper conclude that for nonuniform sediments, the effective size of nonuniform material is related to the median size and the geometric standard deviation and for the determination of scour depth, in the non-uniform bed condition, effect of both size of sediments are taken into account while in stratified bed, bottom layer of finer material should also be considered in effective sediment size calculation.

Sterling Jones at el. (1992) conducted a laboratory study to investigate the effects of footing location on the depth of scour. The study was aimed at evaluating various techniques for characterizing the effective dimensions for a pier or footing combination when both are exposed to the flow field. The HEC-18 pier-scour equation is a design equation used that includes an implicit over prediction factor 1.2 to 1.3. Both the dominant component and weighted pier width techniques are superior to the 10% depth approach in cases in which the footing extends into the flow field. The addresses the significant arresting effects of scour caused by footings located at or below the bed. Footings at such locations can provide effective protection against local pier scour if they are extensive enough.

Vittal at el. (1994) presented paper replaces the solid pier by a group of three smaller piers as a scour reduction device. A group of three cylindrical piers angularly spaced at 120º is studied as a scour-reduction device with three variations, pier group: full, partial and full with collar. The scour due to a pier group in its best orientation is compared with that due to a solid pier of diameter equal to the circumscribing circle diameter of the pier group. They observed that the scour reduction due to a full pier group is about 40%, and 75% of this reduction can be realized by a partial pier group extending into half the flow depth only. Also, the full pier group is seen to be more effective than a solid cylinder with a full slot of width equal to half its diameter and as effective as a solid cylinder with a collar 3.5 times its diameter. A collar on a pier group is much more effective than on a solid pier.

Zafer Bozkus and Osman Yildiz (2004) conducted experimental study to investigate the effects of inclination of bridge piers on local scour depths around bridge piers. Single circular piers inclined toward the downstream direction were founded in a uniform bed material near threshold conditions. The results of this study indicate that the local scour depth decreases as the inclination of the pier (β) increases.

Kothyari at el. (2007) conducted experiment on scour entrainment at piers, at rectangular and sloping abutments, as well as singular and multiple spur dikes. A general criterion is proposed to determine the Densimetric Particle Froude number for scour entrainment. A new relationship for the temporal scour evolution at bridge foundation elements is then developed based on the similitude of Froude by relating the scour depth to the difference between the actual and the entrainment densimetric particle Froude numbers. Studies on the temporal evolution of scour were recently conducted at Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie VAW, ETH Zürich, Switzerland. The new relationship is validated by the complete VAW scour data set, and verified by the available literature data. Based on this new relationship Froude's similitude equation is developed for temporal scour evaluation by considering the effect of element shape.

Umeda at el. (2010) conducted laboratory experiments on the time development of clear water non-uniform cylindrical pier in steady flow. The study aimed at investigating the effects of foundation depth on the scour process. Three-dimensional topography of the scour was carefully measured using digital stereo-photogrammetry as a method to level a riverbed. The spatial distributions of the sediment transport rate were estimated with the variation in the bed elevation. The results show that the process of sediment transport and scour depends on the foundation depth. The retarding and limiting the scour due to the foundation occur when it is placed at an appropriate level below the initial bed level. The scour depth increases with foundation level when the foundation protrudes above the initial bed level. The equilibrium scour depth, scour process and sediment transport are influenced by the relative foundation depth Z/D. For $S_{eD}/D > Z/D > 0$, the equilibrium scour depth is less than that of a uniform pier S_{eD}. For $Z/D = 0$, the scour depth is not very different from SeD. For $Z/D < 0$, the scour depth is larger than that of a uniform pier.

Kothyari and Ashish Kumar (2012) psoposed a new mathematical model for computation of temporal variation of scour depth at circular compound bridge piers. In the first series of experiments, the data on temporal variation of scour depth were collected. The second series of experiments was carried out to measure the size and hence the area of the principal vortex of the horseshoe vortex system. They focuses on the temporal variation of scour in compound bridge pier with varying footing level w.r.t. channel bed level i.e., footing above the bed level, footing at the bed level, and footing below the bed level. When dst<Y: the circular compound pier in this case acts as a circular pier having diameter b and there is no effect of the footing on the scour until the scoured bed reaches up to the top surface of the footing. When ds≈Y: The condition $Y = 0$, i.e., the scenario that the top surface of the footing is at the bed level is also covered under this condition. In such a case, the principal vortex first rests on the top surface of footing at the upstream nose of the pier.

Kothyari at el. (2014) conducted experiment in cohesive sediments. The sediment used for the experiment were of two types: fine gravel mixed with clay in proportions varying from 20% to 60% by weight; and fine gravel and fine sand in equal proportion by weight mixed with clay in proportions varying from 20% to 60% by weight. The experiments revealed that the process of scour as well as depth, shape, and geometry of scour hole developed in such cohesive sediment were significantly different from that of cohesionless sediments. Proportion of clay fraction and unconfined compressive strength of cohesive sediment mixture were found to be the most significant variables controlling the depth of scour in the wake of piers. On the basis of dimensional considerations, relationships have been proposed for the estimation of the depth of scour in the wake region of piers in clay-gravel and clay-sand-gravel sediment mixtures. From the experiment, they concluded that Maximum depth of scour almost invariably occurs at the upstream nose of the pier in cohesionless sediments, whereas significant scour took place in the wake zone of piers in cohesive sediments. Moreover, in some cases negligible to zero depth of scour was observed at upstream nose of piers in the case of cohesive sediments.

Yadav and Ram (2014) conducted study with overall objective of the research is to study the temporal development of the scour for a pier fitted with a collar and a pier without a collar. The study was conducted using a physical hydraulic model operated under clear-water conditions in cohesion-less bed material. The time development of the scour hole around the model pier with and without a collar installed was compared with similar studies on bridge piers. The depth of the scour hole increases as the duration of the increased flow that initiates the scour increases.

Deshmukh and Raikar (2016) conducted experimental study and investigated a clear water scour under unsteady flow for a circular pier. For that they used three different stepped flood hydrographs; advanced, symmetrical and delayed flood hydrographs of same base period for two uniform sediments size having d50 of 0.52mm and 0.712mm. The experimental result shows that non dimensional scour depth is independent on pier diameter but is dependent on mean sediment size. The parametric study reveals that scour depth under unsteady flow also varies proportional to pier diameter of circular pier and type of flood hydrographs based on steps of flood hydrographs. Final scour depth observed for delayed flood hydrograph is maximum for sediment of d50=0.52mm and a scour depth determination expression for symmetrical flood wave is more reliable than others. Dimensionless scour depth is dependent on mean sediment size.

III. CONCLUSION

Many previous researchers have studied the temporal variation of scour depth and provided empirical formulas with proper validation. Their study was mostly by varying pier size, shape, flow conditions, different sediment proportions and scour reducing devices.

Temporal variation of scour for different flow conditions steady and unsteady flow with different bed conditions uniform bed, nonuniform bed or stratified bed lying in the flume was carried out and observed that the various parameters affecting scour are median size and geometric standard deviation. The temporal variation of scour was also calculated for pier having circular and rectangular shape and for sloping abutment, singular and multiple spur dikes. Effect on maximum scour depth varying the footing level with respect to bed level i.e. above bed below bed or at bed level was also carried out. Various proportions of sediments were also selected for bed preparation, conducted experiments and studied and concluded that process of scour as well as depth, shape, geometry were different for cohesive and cohesionless sediment. Inclined piers, collars and pier groups also taken as variation for scour depth variation.

For all the variations and study, different hydraulic parameters and empirical equations were used. Among these all, my research work is carried out for nonuniform sediment bed having uniform flow condition for a single slope varying the proportions of sediment under clear water flow condition. Then the observed data of experiment will compared with mathematical model for validation. The varying parameters are depth, discharge, velocity, mean size of bed sediment.

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