Journal of Water and Soil
Vol. 30, No. 6, Jan.-Feb. 2017, p. 1860-1873

نشریه آب و خاک (علوم و صنایع کشاورزی)
جلد 30، شماره 6، بهمن – اسفند 1395، ص. 1873-1860

Simulation of Flow Pattern around Inclined Bridge Group Pier using FLOW-3D Software

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Received: 08-08-2015
Accepted: 19-06-2016

Introduction: Bridges are certainly one of the most important structures but costly service elements in a transport system. The bridges are very required to access the damaged areas in emergency situations such as floods and earthquakes. Scour around the foundations of bridge piers exposed to the flowing water than can destroy the bridge itself is a subject of major concern. Flow pattern is known as responsible for all changes in stream bed. Any obstacle in the channel can form new flow patterns causing additional shear stress exerted on the bed than the equilibrium condition of the absence of the obstacle. Appropriate shaping of flow pattern and proper selecting of pier geometry and the location of bridge piers can be one of the proper methods in reduction of scour amount which is the main subject of the present study.

Materials and Methods: Inclined bridge group pier is a type of bridges with modern geometry based on development in building technology of structures. Many of these bridges have been built all around the world and the 8th bridge built crossing the Karun River in Ahvaz is a sample of the Iranian ones considered in this research. Hydrodynamic behavior of flow is investigated around the inclined bridge group pier settled on foundation using the FLOW-3D numerical model. Inclined bridge group pier investigated in this study, includes two rectangular piers which are 2.5 cm long and 3.5 cm wide and set in an angle of 28 degree on rectangular foundation which is 16 cm long and 10 cm wide and installed in three different foundation levels namely at, above and below the bed levels. The physical model of prototype pier considered in this study was constructed to the scale of 1:190 of the Ahvaz 8th bridge. In order to verify the accuracy of the numerical model, velocity data obtained from image processing technique were used.

Results and Discussion: Due to non- linearity and interactions between various phenomena involved, flow pattern around the piers group is entirely different than that for a single pier and consequently the outcomes of the flow pattern around single pier cannot be generalized to the pier group. At all levels of foundation setting, longitudinal component of flow velocity increases surrounding the first pier. The increase in the area and its extension towards downstream is caused by the constriction the flow due to the pier and area rotating of the wake vortex in downstream. When the pier foundation is set at the stream bed, the bed rotating flows extend to a distance between the two piers from near the bed up to the middle of flow depth while in upstream of the second pier and near water surface, the stream lines become parallel to the bed. The comparison of the results of the changes in bed shear stress in the situations of foundation setting in different levels showed that the maximum shear stress occurred when the foundation level is at the bed level and the maximum shear stress exerted on the bed decreases by factors of 17% and 53% in the cases of foundation level to be below and above bed levels, respectively. In addition, the results showed that, the amount of vortex flows increased in upstream piers group and near bed in the case of setting the foundation above the bed. This is because of the fact that the volume of piers group acted as obstacle against flow was more than other level settings. Furthermore, based on the obtained results, in the case of foundation level is set at the bed, the quantity and development zone of vortex flow are much higher than those observed when the setting foundation is below the bed level. This can be attributed to the higher effect of the second pier on the flow pattern being between the first and the second piers. Stream lines turn downward in the range between piers group, and after the collision to bed turn upward to water surface and cause to form rotating flow and hence high turbulence intensity in the area. In the near water surface and the center of group piers, stream lines were observed to be parallel to the bed and caused low turbulence intensity in this area.

Conclusions: The results showed that the levels of setting foundation have a significant effect on hydrodynamic characteristics and flow pattern around the piers. By increasing the dimensionless height of the setting foundation from -1 to 0.5 vortices formed in the downstream piers group is strengthen more and the

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results from the numerical model are consistent with the results of experimental scour around piers group in all three levels of setting foundations. When the foundation setting is at the bed level, the maximum bed shear stress is observed. The maximum bed shear stress is decreased by factors of 17 and 53 percent when the foundation to be set below and above bed levels, respectively.

Keywords: Ahvaz 8th bridge, Flow pattern, Foundation level, Image processing method, Inclined bridge group pier, Numerical model FLOW-3D