Effect of abutment aspect ratio on clear-water scour in floodplains

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Abstract

Scour around abutments is recognized as one of the main reasons of bridge foundations failure. This paper presents the experimental results of the effects of abutment width and length on the scour development up to its equilibrium condition around 45° wing-wall setback abutments in a compound channel. The developing scour hole characteristics are tested for three different lengths and widths at different time intervals until its equilibrium scour conditions. The findings showed that the abutment width has a profound effect on the characteristics of the scour hole, contradicting the results of previous studies. Generally, an increase in the relative abutment width leads to a reduction in the scour depth and width. However, the scour length, area, and volume initially increase with an increase in the relative abutment width, $L_c/y_f$, from 1.33 to 10.67, where $L_c$ is the abutment width and $y_f$ is the floodplain flow depth, and then these characteristics decrease significantly with a much wider abutment, $L_c/y_f$, from 10.67 to 21.33. Overall, the effects of the abutment width on abutment scour should be accounted. To this end, empirical equations are proposed to predict the scour hole characteristics. Scour data from previous studies are also used to compare with the proposed equations.

KEYWORDS

abutment width, compound channel, floodplain, scour hole characteristics, setback abutment

1 | INTRODUCTION

Scour is defined as the removal of boundaries (banks and bed) of rivers by the action of moving water (May, Ackers, & Kirby, 2002). After construction of bridges across rivers, the localized velocities increase around the foundation of these structures because of the reduction of the flow cross-section area between bridge openings, and this often causes local scour around these structures. This phenomenon threatens the stability of the bridges. Since 1960, it was reported that the foundation scour is the main reason for 60% of bridge failures in the United States (Shirole, 1991). Hence, it is important to monitor for scour around these structures to ensure that the localized scour is within the permissible ranges.

Natural streams and rivers commonly consisted of a main channel and one or two floodplains in accordance with their effective discharge and geomorphic changes that occur along the river path. Several studies have investigated on abutment scour in rectangular channels (Cardoso & Fael, 2010; Dey & Barbhuiya, 2005; Gill, 1972; Kandasamy & Melville, 1998; Laursen, 1960; Lim, 1997; Liu, Chang, & Skinner, 1961; Melville, 1992; Oliveto & Hager, 2005). Richardson, Harrison, Richardson, and Davis (1993) pointed out that abutment scour in two-stage channels cannot be represented by the results from rectangular channels. Moreover, Ettema, Nakato, and Muste (2010) and Hong (2012) remarked that many predictive formulas for abutment scour overpredict the scour depth, and one reason is that the effects of the geometry of a channel, particularly for compound channels, have not been fully accounted for in the predictive equations.

Scour around setback abutments in compound channels has been studied by few researchers such as Sturm and Janjua (1994) and Sturm (2006) who reported that the scour depth in compound