Migration of Maximum Scour Location around Wide Setback Bridge Abutments in Floodplains

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Abstract: Location of maximum scour depth is a key feature for the accurate design of scour countermeasures. Experimental results show that the maximum scour depth around wide setback abutments migrates to a location further downstream than that observed conventionally at the tip for narrower abutment. The wide abutment caused two scour holes to form, with a larger primary scour hole and a smaller secondary scour hole downstream from the first, and this has important implications for scour protection at the structure's foundation. For this study, 55 experiments were conducted with seven abutment aspect ratios and the migration of the maximum scour locations were measured. The results reveal that R_x (the normal distance from abutment face to the location of maximum scour depth) is affected by the flow intensity, flow depth, and abutment aspect ratio. The value of R_x is larger as flow intensity decreases for the same abutment aspect ratio. However, R_y (the distance from the centerline of abutment face to the location of maximum scour depth parallel to flow direction) is only affected by flow depth and abutment aspect ratio. Empirical equations are proposed to predict the locations of the maximum scour depth for wide abutments in compound channels. **DOI: 10.1061/(ASCE)IR.1943-4774.0001599.** *© 2021 American Society of Civil Engineers.*

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Introduction

Bridges play a substantial part in any transportation network and there are many bridges constructed over rivers and streams. The construction of bridges facilitates the movement of people and goods across riverbanks. Nevertheless, their foundations may be subjected to localized flow contraction and scour due to a reduction of flow cross-section area and an increase in local velocities at the bridge locations (Abdelaziz and Lim 2017; Younes 2019).

Many researchers have studied scour around bridge foundations because it may threaten the stability of the foundations and lead to the damage of these bridges, and may also result in loss of life. During the past 50 years, 60% of the thousands of bridge failures in the United States were reported to be associated with foundation scour (Shirole and Holt 1991; Lagasse et al. 2007). These failures cause large financial losses in terms of rehabilitation and reconstruction. Therefore, it is important to monitor for scour around these structures to ensure that the localized scour is within the permissible ranges.

Riprap is commonly used to protect bridge foundations against the possible scour around them. There are four types of failure for riprap apron, namely, winnowing failure, edge failure, shear failure, and bed-form undermining (Chiew 1995; Melville et al. 2006). The edge failure mainly occurs due to inadequate provision of the size of the apron. Hence, it is important to know the exact location of the maximum scour to prevent this type of failure. This study shows that the location of the maximum scour depth is not necessarily at the tip of the abutment, as was found in many previous studies. In addition, the majority of these studies focused on the prediction of maximum scour depth around abutment sited in rectangular channels (Gill 1972; Melville 1992, 1997; Lim 1997; Oliveto and Hager 2002, 2005; Dey and Barbhuiya 2004; Cardoso and Fael 2010). Richardson et al. (1993) reported that results of abutment scour in two-stage channels are different from those in rectangular channels. Review shows that abutment scour in compound channel was studied by few researchers such as Sturm and Janjua (1994), Melville (1995), Kouchazadeh and Townsend (1997), Cardoso and Bettess (1999), Lim and Nugroho (2003), and Sturm (2006).

With reference to the scour hole characteristics, Kuhnle et al. (1999) reported that the shape of a scour hole has a profound effect on the aquatic habitat and stability of bank. Van Ballegooy (2005) and Melville et al. (2006) observed the locations of maximum scour depth around erodible spill-through (ST) setback abutment with riprap and cable-tied block scour countermeasures in compound channels. They found that as the abutment length increases, the maximum scour location shifts away from the abutment face. In addition, as the apron width increases, the scour hole migrates further away from the abutment face. They also remarked that the maximum scour location is not affected by the floodplain width and it is especially useful for the design of scour countermeasure because the maximum scour depth location is not at the abutment tip as observed for narrow abutment but is further downstream. Ettema et al. (2010) pointed out the location of maximum scour depth can shift from a location far from the abutment tip to a point nearer to the bank line of the channel. This will threaten the geotechnical stability of the bank line between the floodplain and main channel, resulting in its failure.

Zhang et al. (2012) studied the maximum scour location around a vertical wall (VW) abutment in a rectangular channel and concluded that the maximum scour at high flow intensity was near the abutment tip because of the continuous strong vortex action. On the other hand, for low flow intensity, the relatively weaker flow caused the vortex formation to be further from the abutment face, which deflected the maximum scour location laterally. As a result, as the flow intensity decreases, the location of maximum scour

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