EXPERIMENTAL STUDY ON LOCAL SCOUR AT EMBANKMENT TOE DUE TO OVERTOPPING FLOW

Saitama University Student Member ○ Md Masum Billah
Saitama University Regular Member Junji Yagisawa

1.INTRODUCTION

Earthen embankment is very effective to withstand against flood, tidal surge, tsunami and other natural disasters but failure of this embankment due to overtopping is about 40-48% of all reported case of failure, Jandora and Riha(2009). Equilibrium scour depth at toe depends on velocity, flow depth and particle size during overflow, Bormann, et al. (1991). Velocity, overtopping depth and geometry of structure are considered to be important factors for predicting maximum scour depth and length, Afreen et al. (2016). Headcuts are drop in bed level that occur at the heads of channel networks and may finally result in gulley formation. Small headcut at landside toe of embankment is formed initially and it starts to propagate upstream with time. Limited research on headcut development indicates that the dimension of scour depends on upstream flow condition, nappe characteristics, initial headcut height and bed materials. As initial headcut height increased, maximum scour depth increased, length to maximum scour depth decreased, and headcut aspect ratio decreased. The jet entry angle also increased as initial height increased, Bennett et al. (2000). In this study, effect downstream slope of embankment, upstream flow condition and initial headcut height on headcut scour at toe have been investigated.

2.OBJECTIVES OF THE STUDY

To know the effect of initial preformed headcut height, downstream (d/s) embankment slope and upstream (u/s) hydraulic condition on local scour at landside toe.

3.METHODOLOGY

This study has been done through the experiment in Hydraulic and Environmental Engineering Laboratory of Saitama University, Japan. In the large depth channel of the laboratory, initially two embankment models of 1:2 and 1:3 downstream slopes were prepared for the experiment. Three different discharge low (10.0 m^3/h), medium (15m^3/h) and high (20.0m^3/h) were selected for checking effect of varying upstream hydraulic conditions. Gravel having D_{50}=4.50mm was used as bed material. Also three different preformed headcut heights, h_1, at toe of the d/s embankment were chosen as 5, 25 and 50 mm. Then after overtopping flow for 5 minutes, scour hole dimension (S_L (scour length) and S_D (maximum scour depth)) was measured for all eighteen cases with measuring scale as well as 2D LASER device. The schematic diagram and image of experimental set-up as well as typical scour hole at toe are shown in Figure-1.

Figure-1: Schematic diagram (left), Image of experimental setup at laboratory (middle) and Typical scour hole (right)

4.RESULTS AND DISCUSSION

Three discharges 10m^3/s, 15m^3/s and 20m^3/s showed maximum scour depth 5.0cm, 5.5cm and 6.5cm respectively for 1:2

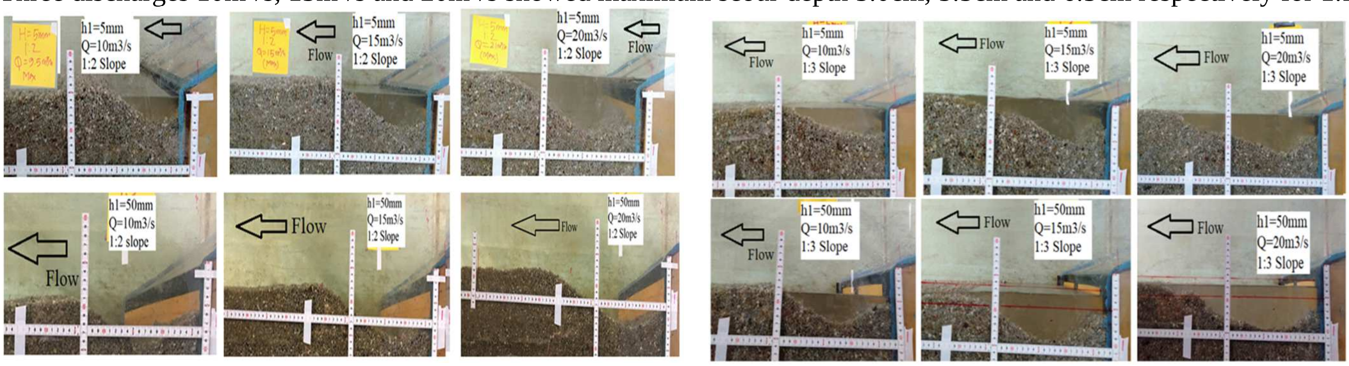

Photo-1: Image of scour profile at toe of embankment for 1:2 slope (left) & for1:3 slope (right)

Keywords :Scour, Headcut, Embankment, Toe scour, Landside toe, Scour hole, Overtopping, Impinging angle
Contact address: 338-8570, 255, Shimo-okubo, Sakura-ku, Saitama, E-mail: yagisawa@mail.saitama-u.ac.jp

d/s slope whereas this value was 3.0cm, 5.0cm and 5.5cm respectively for 1:3 d/s slope irrespective of initial headcut height and maximum scour length was 22cm, 27cm and 31cm respectively for 1:2 slope whereas these values were 23cm, 29cm and 38cm respectively for 1:3 slope having 50mm preformed initial height. The results showed that the maximum scour depth at toe was 6.5cm for 1:2 slope and maximum scour hole length was 38cm for 1:3 slope for maximum discharge 20m^3/s. In Photo-1, scour profiles have been shown as 5mm on top row and 50mm on bottom row for discharge 10m^3/s, 15m^3/s and 20m^3/s respectively. The scour profile for 1:3 d/s slope condition showed that the highest scour position was far from toe compared with 1:2 d/s slope. Beside this, bottom slope of scour hole is gentler for 1:3 slope compared with 1:2 slope because impinging angle is higher for steep slope. The plot of discharge versus maximum scour depth from original bed level shows that depth increases with increases in discharge irrespective of initial height for both slopes condition. This is because of tail water level and plunge pool effects, as impinging jet cannot erode and get deflected due to effect of high tail water depth for 5mm headcut height as in Figure-2 (a1 & a2).

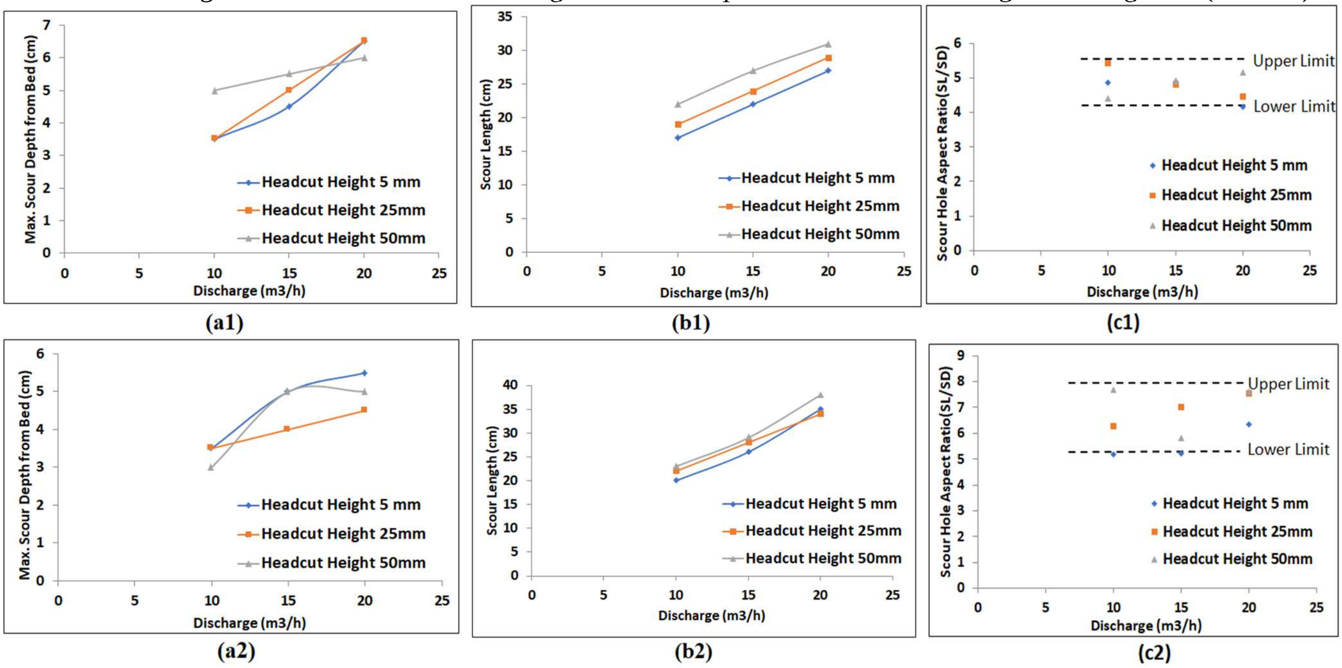

Figure-2: Effect of preformed headcut height (h_1) and discharge on scour dimensions
(a): Variation of Max. scour depth (a1; downstream slope 1:2, a2 : downstream slope 1:3), (b): Variation of scour hole length (b1; downstream slope 1:2, b2 ; downstream slope 1:3) and (c): Variation of scour hole aspect ratio (c1; downstream slope 1:2, c2; downstream slope 1:3)

In figure-2 (b1&b2), it can be also observed that length of scour hole increases with increase in either initial headcut height or discharge for both 1:2 & 1:3 slope. Stepper slope (1:2) showed lower aspect ratio (S_L/S_D) of scour hole, here for d/s slope 1:2 scour hole aspect ratio varies from 4.15-5.43 and for 1:3 slope scour this value varies from 5.20-7.67, this happens because of impinging jet angle effect. Lower aspect ratio indicates maximum scour depth was close to toe and more dangerous for embankment and high aspect ratio stands for large area and properties affected on landside.

5.CONCLUSION

Scour length and depth increase with increase in headcut height and/or discharge. Although depth increases by small amount compared to length. More response was noticed in increase of_length_of scour hole. With the increase in d/s slope maximum scour depth increases irrespective of initial headcut. Scour depth was maximum for 1:2 slope and scour length was maximum for 1:3 slope for same discharge. Stepper d/s slope (1:2) showed lower aspect ratio for scour hole compared to flatter slope 1:3. Hence initial preformed headcut height has significant impact on toe scour shape and size so earlier preventive measure should be taken for reducing risk of embankment failure and properties affected on landside.

REFERENCES

Afreen, S., Yagisawa, J., Binh, D. Van, & Tanaka, N. (2016). Investigation of Scour Pattern Downstream of Levee Toe Due to Overtopping Flow. Journal of Japan Society of Civil Engineers, Ser. B1 (Hydraulic Engineering), 71(4), I_175-I_180

Bormann, N. E. and Julien, P. Y. (1991) Scour Downstream of Grade–control Structures, Journal of Hydraulic Engineering, Vol. 117, No. 5, pp.579-594, 1991

Bennett,S.J.,Alonson,C.V.,Prasad,S.N.& Römkens,M.J.M. (2000). Experiments on Headcut Growth and Migration in Concentrated Flows Typical of Upland Areas. Water Resources Research 36(7): 1911–1922.

Jan Jandora and Jaromir Riha,(2009) The Failure of Embankment Dams Due to Overtopping.,Václav Houf 2008, ISBN 978-80-214-3527-8