Impact of Large Wood Debris (LWD) Accumulation on Scour Characteristic at Bridge Pier

Abubakar Siddiq[1], Ghufran Ahmed Pasha[1], Usman Ghani[1], Afzal Ahmed[1]

[1]*Department of Civil Engineering, University of Engineering and Technology, Taxila*

***Abstract*: During extreme floods, accumulation of Large wood debris (LWD) at upstream of bridge piers effects the stability of piers. They cause additional forces by deviation and reducing area of flow, which influence hydraulic structures and exacerbate scour. During 2010 floods in Pakistan, more than 278 bridges were collapsed only in KPK Province. Most of them were collapsed due to LWD accumulation. The present study presents results from flume experiments performed at Hydraulics Engineering Laboratory of Civil Engineering, University of Engineering and Technology, Taxila. The circular pier was used in a channel and the debris were allowed to float at the water surface and hit the bridge pier at various heights. On the scour generation mechanism due to various stuck position of debris with respect to depth of water flow H and pier diameter D was investigated. A false bed of 6 m long, 0.96 m wide and 0.17 m depth was provided in laboratory channel to stimulate the scour zone. All the tests were performed under clear water condition. The scour generated at upstream was compared with local scour hole that occurred without debris flow . Based upon the observation and analysis of the experimental data and used setup, the result showed that the debris stuck at the height of 0.75 D generated more scour as compared to that of scour hole generated due to isolated pier as well as flowing debris at the top surface. Further decrease in accumulation height reduces the scour hole and act as pier collar.**

***Keywords*: Bridge Pier, Large wood debris (LWD), height variation, scour mechanism**

I. INTRODUCTION

The annual flood report describes the bridge pier failure, which is caused either by flood or the accumulation of large wood debris (LWD) at the front of bridge pier in the northern areas of Pakistan--during flood of 2010. This indicates the lack of knowledge of debris accumulation and its remedial measures causing obstruction to flow, accelerating the bridge pier scour process and results in bridge failure. Below Fig 1 shows some pictorial view of 2010 floods in Pakistan (FFC Report, 2010).

Fig 1: Bridge collapse during 2010 flood on river swat

Local scour on bridge piers in clear water condition is broadly considered along with scour geometry, and temporal evaluation generated by single or multiple piers with several geometric, hydraulic and sediment conditions, even in presence of protection structures. Several scour prediction equations have been established. Amongst others, Raudkivi and Ettema (1985), Laursen (1958), Shen at al. (1969), (Melvill and Sutherland (1988), Richardson and Davis (2001), Melville (1997), and Raikar and Dey (2008), Franzeetti et al. (1994), Chiew (1995), Kandasamy and Melville (1998), Tang et al. (2009), Zarrati et al. (2010), Masjdi et al. (2010)- studied the effect of flow shallowness, intensity, sediment roughness, and pier shapes on the maximum equilibrium scour in presence of isolated bridge piers, as well as countermeasures- to reduce the maximum scour hole depth (collars, rip-rap and tetrahedral frames). Pagliara and Carnica (2011) studied the effects of (LWD) frontal formationon bridge pier scouring.

The aim of this experimental study was to estimate the effect of LWD accumulation on circular bridge pier scour under clear-water conditions, which means the mean velocity of the flow is at the threshold or below the threshold velocity at the start for un-disturb approach flow. Different types of experiments were conducted i.e. debris flowing freely on top surface and then changing height of debris w.r.t depth of water up to bed level. After sorting the maximum scour height, changing length of debris and porosity, the effects of scour generation was measured. The scour developed from each experiment were compared to find out the effect of debris accumulation.

II. MATERIALS & METHODS

A. *Flume characteristics*

All the tests were performed in the Hydraulics Laboratory of Department of Civil Engineering, University of Engineering and Technology, Taxila. The test channel was 20 m long, 0.96 m wide and 0.75 m deep, provided with glass side walls and concrete bottom is used for experimental purpose. The discharge is supplied through pump from a side tank by aligned honeycomb diffuser in the direction of flow for smooth and uniformly distribution of flow cross-wise. The water is then discharged into the stilling tank provided at the tail end of the channel. After filling and trapping the flowed sediments, the flow discharges in the main channel. Fig 2 shows the plan view of the channel as well as experimental setup. A false bottom of medium size, uniform sand, 6 m long, 0.17 m deep and 0.96 m wide was introduced as pier base and bed material. The bed at upstream up to 2 m long, 0.96m wide and 0.17 m deep provided the transition between the scoured zone and water entrance zone of the channel. Medium river sand material was used as false bed satisfying the range of granulometric characteristics given by Raudkivi and Etema (1983), Oliveto and Hager (2005), to avoid the formation of bed forms and cohesive effects of sediments, the size of sediments should be d50> 0.9. and for neglecting the armouring effect, σ < 1.3. where dxx is the diameter in which xx percent material is finer, σ = ½(d84/d16) the standard deviation of sediments.

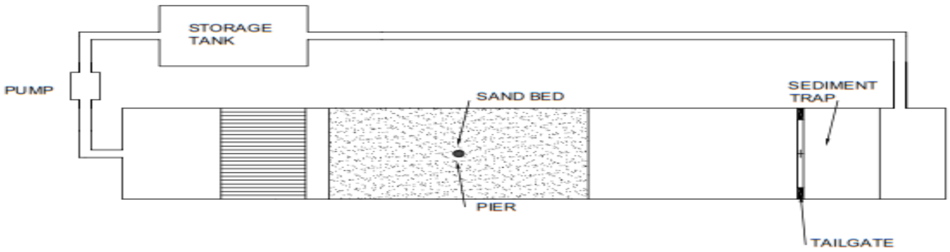

Fig 2: Plan view of Laboratory Flume

B. *Debris accumulation*

The pier was modelled by 0.06 m diameter PVC pipe, and the debris accumulation was simulated by bonding them together with the help of metallic string. At start the test was performed as pilot test with no debris and then introducing the debris at the top, then reducing the stuck position of debris with respect to the pier, reducing the height with respect to the diameter of the pier, different tests were performed at the height of 2.3D, 2.0D, 1.5D, 1.0D and 0.5D respectively. At a depth of 1.0D the scour was observed maximum than the previous experiments, while the minimum scouring was observed at the depth of 0.5D. Rest of the experimental cases were performed between the 1.0D and 0.5D depth. Various parameters used in the experiment are shown in Fig 3.

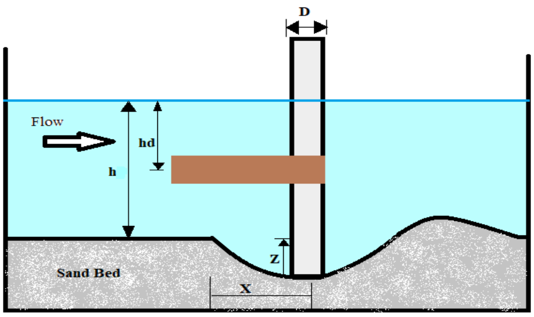

Fig 3: Pictorial representation of scour due to LWD

C. *Experimental Procedure*

Before performing each experiment, the sand bed was carefully levelled with the upstream and downstream flume bed. The pier was placed at the center and inserted in sand bed up-to flume bed. The discharge was then allowed to enter flume gradually and attained high depth and low velocity with the help of tailgate. The discharge was set and flow was then regulated manually to maintain constant depth and the discharge after stabilizing all conditions. The experiment time was then started when the depth of water is achieved. After completion of experiment, the pump was then turned off and the flume was drained slowly. After complete drained, the scour was measured with the help of point gauge having accuracy of ± 0.5 mm. The test was allowed to run for minimum 3 hour as 95% of the local scour obtained in 80 minutes. Further scour generated due to long time flow was less than 1 mm from the observation of temporal variation (Rahimi 2018). Thus the average time taken was 3 hr. After completing the above process, the geometrical dimensions of the scoured hole were measured.

III. RESULTS

Several experiments were performed with various stuck position with respect to height of pier. The analysis below demonstrates the effect of the stuck position on scour generation. The cases and results of different hydraulic parameters used in current study are listed in Table 1. Where *Q* is the discharge, *Y* is the flow depth, *Ds* is the scour generated at piers with respect to stuck position, *hd* is the depth of water level from the top free surface and d is the depth of stuck position of LWD with respect to pier.

Table 1: Hydraulic parameters of present studies

Case	*Q(CMS)*	*h/d*	h_d/d	*T (hr)*	*Y(m)*	*Ds (cm)*	*Ds/dr*
1	0.025	2.5 (N)	0	3	0.15	2.3	-
2	0.025	2.5	0	3	0.15	3.1	1.34
3	0.025	2.0	0.2	3	0.15	3.3	1.43
4	0.025	1.5	0.4	3	0.15	3.7	1.60
5	0.025	1.0	0.6	3	0.15	3.9	1.69
6	0.025	0.75	0.7	3	0.15	4.2	1.82
7	0.025	0.62	0.75	3	0.15	3.48	1.51
8	0.025	0.55	0.77	3	0.15	2.46	1.06
9	0.025	0.5	0.8	3	0.15	2.0	0.87
10	0.025	0.3	0.88	3	0.15	1.8	0.78

The LWD were mounted at the different location with pier (2.5D, 2.0D, 1.5D, 1.0D, 0.75D, 0.62D, 0.55 D, 0.5D, and 0.3D) where D represents diameter of pier. During experiments, it was observed that the maximum scour depth increase by increasing the relative depth of debris and attain maximum depth at 0.75 D. Fig. 4 show the attained scour depth with reference to pier diameter at different stuck positions.

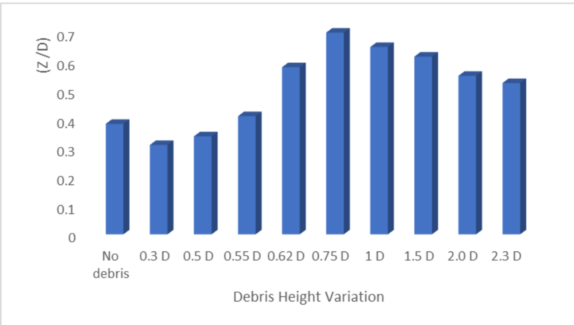

Fig 4: Maximum scour near pier due to different height

By performing experiments, the results showed that the scour depth increase with height variation of debris and reach to maximum value at the relative submerged depth of 0.75 D. By further increment, the scour depth decrease and at last it cause scour reduction more than that of scour generated by pier without debris. *(Rahimi 2018)* found that due to increase in distance between the free flow surface and the debris, the jet of down flow increases, and further increment reduces the scour depth and acts as pier collar.

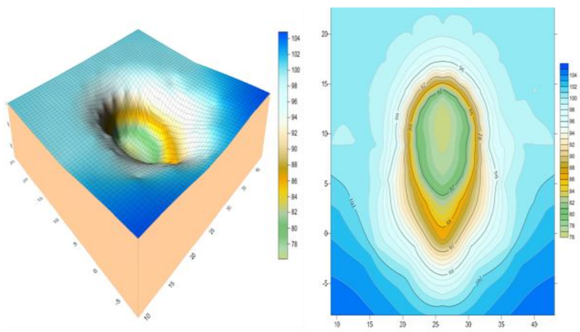

Fig 5: a) 3D view of scour generation due to 0.75 D. b) Contour map of scour hole

Fig. 6 shows the relationship between non-dimensional scour depth denoted by *Z/D* and the non-dimensional longitudinal distance from the center of the pier, denoted by *X/D*. The scour hole generated due to LWD at the upstream side shows two types of slope; the slope is mild at the start of scour hole, while the scour slope becomes steep near the bridge pier.

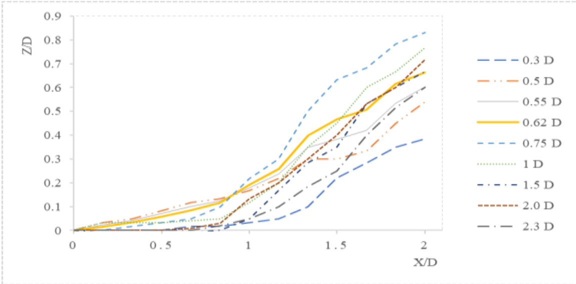

Fig : 6 Longitudinal maximum scour profile

With the increase in *hd/d* ratio, the scour hole was mild in the start of scouring hole, after that a steep slope occurs near the pier, which acts as pier collar.

IV. CONCLUSIONS

In this experimental study, the scour pattern around single circular pier with varying heights of debris accumulation were investigated. The experiments were performed without debris and with debris accumulation at upstream of pier with different heights.

At the start, when debris were allowed to stick with the bridge pier at free surface of water, minimum scouring were observed. However, the depth of scour hole was increased with the decrease in debris accumulation height. Further reduction in depth of LWD, the scour hole reached to a maximum value and after that the scour hole started to decrease.

The maximum scour was observed at the depth of 0.75D. Further increase reduces the scour and the debris act as pier collar.

REFERENCES

[1]. Pagliara S. and Carnacina I. (2010). "Temporal scour evolution at bridge piers: Effect of wood debris roughness and porosity." *Journal of Hydraulic Research, Vol. 48, No. 1, pp. 3-13.*

[2]. Pagliara, S. and Carnacina, I. (2011). "Influence of large woody debris on sediment scour at bridge piers." *International Journal of Sediment Research, Vol. 26, No. 2, pp. 121-136, DOI: 10.1016/S1001-6279(11) 60081-4.*

[3]. Melville, B. W. and Dongol, D. M. (1992). "Bridge pier scour with debris accumulation." *J. Hydraul. Eng., Vol. 118, No. 9, pp. 1306-1310.*

[4]. Melville, B. W. and Hadfield, A. C. (1999). "Use of sacrificial piles as pier scour countermeasures." *Journal of Hydraulic Engineering, Vol. 125, No. 11, pp. 1221-1224.*

[5]. Parola A. C., Apelt C. J., and Jempson M. A. 2000, Debris forces on highway bridges. NCHRP Report No. 445, *Transportation Research Record, Transportation Research Board, Washington, D.C.*

[6]. Parola A. C., Kamojjala S., Richardson J., and Kirby M. 1998, Numerical simulation of flow patterns at a bridge with debris. *Proceeding of Water Resource Management, Reston, VA, pp. 240–245.*

[7]. Raikar R. V. and Dey S. 2008, Kinematics of horseshoe vortex developing in an evolving scour hole at a square cylinder. *Journal of Hydraulic Research, Vol. 46, No. 2, pp. 247–264.*

[8]. Raudkivi A. J. and Ettema R. 1983, Clear-water scour at cylindrical pier. *Journal of Hydraulic Engineering, Vol. 109, No. 3, pp. 338–350.*

[9] Richardson E. V. and Davis S. R. 2001, Evaluating scour at bridges. Report No. FHWA–NHI–01–001, Hydraulic engineering No. 18 (4th edition), *Federal Highway Administration, Washington, D.C.*

[10]. Federal Flood commission, Ministry of Water & Power; *Flood report 2010*

[11]. E. Rahimi, K. Qaderi, M. Rahimpour, and M. M. Ahmadi, "Effect of Debris on Pier Group Scour: An Experimental Study," *Journal of Civil Engineering, pp. 1–10, 2017.*