Experimental study of railway bridge scouring and proposal of remedial measures- A case study of bridge number 30, Harrow River.

Muhammad Sohail Javed1,3,a, Naeem Ejaz2,b
1 Civil Engineering Department, University of Engineering and Technology, Taxila, Pakistan.
2 Civil Engineering Department, University of Engineering and Technology, Taxila, Pakistan.
3 Pakistan Railways, Rawalpindi Division, Pakistan.

Abstract. Bridges are one of the most integral transportation components for connection of remote parts worldwide. The concern of every engineer is with their stability and collapse. One of the issues with bridge stability is bridge pier scouring in perennial and inundation canals as well as rivers. If not properly monitored and precautionary measures not adopted, it can result into bridge collapse. This paper makes an attempt to study the heavy bridge scouring in Railway Bridge (bridge # 30) on Harrow River located at downstream of Khanpur Dam, Pakistan. The study is carried out experimentally on scaled down model of bridge to study the behavior and patterns of scouring in the river bed during and after floods in two phases including 1) investigating the causes of scouring 2) provision and analysis of suitable remedial measures. The scouring that occurred in lab model matched the field patterns. Baffle walls and weir were provided separately as remedial measure but the former failed under initial watering while weir provided on downstream side reduced scouring by 95%.

Keywords—bridge, scouring, experimental model, remedial measures, baffle walls, weir

1. Introduction
Scouring is a natural phenomenon of water carrying away sediments from river bed and riverbanks, around the bridge piers and abutments caused by erosive action of the flowing water of alluvial channels. The construction of bridges in alluvial channels causes a contraction in the waterway at the bridge site. Resultantly, this contraction in the waterway causes a significant scour at that site. Many bridges tailed around the world because of extreme scour around piers. The vertical reduction in the river bed measured from bed level is called scour depth (Thamer et al. 2005). The longitudinal and transverse extents of scour increase with scour depth. The volume of scour hole increases quadratically with maximum scour depth after 24 h. (Rashid Farooq, August 2019). Studies reveal that maximum scour takes place on the upstream and side of the pier. Accordingly, efficacy of scour protection measures such as raft foundation, cut-off walls can be studied and verified. (Bruce w.melville). For live-bed scour, the existence of a downstream submerged weir can cause upstream bed aggradations, reducing the scour depth at the pier (Lu Wang, 2018).
2. Objectives:
The aim of this research is to experimentally stimulate bridge scour conditions of Railway bridge number 30 on Harrow River, Pakistan. After stimulation the causes are to be investigated and then suitable remedial measures to be provided and their efficacy experimentally checked. Finally, scour prevention measures based on experimental verification to be proposed for the respective bridge in field.

3. Experimentation:

3.1. Case study description:
Pakistan Railways is one of the biggest state owned organizations. Bridges having single clear span more than 60 ft are called major bridges in Pakistan Railways. Bridge #30 is a major (12 spans of 65 feet) and one of the most important bridges for CPEC project. Being on downstream of Khanpur dam there is always a threat of flood situation. B # 30 was completely washed out in year 1997 floods and then it was reconstructed in year 2000. But again in 2007, due to heavy flood in Khanpur dam, the high water velocity eroded the bridge bed and 30 feet deep channel was formed along with 20’ piles which were exposed to environment. For temporary cater of scouring 13000ft³ stones were laid around bridge but it did not prove to be of any great significance. The bridge sections are shown in figure 1 and 2.

3.2. Experimental set up of model and river bed:
This study was carried out in a flume of fixed slope with a length of 10 m and a width of 0.96m at Hydraulic Laboratory of University of Engineering And Technology, Taxila. Depth, flow and velocity of water was controlled both by valve of inlet pipe at upstream of flume and controlled gate at the end of downstream of flume. Velocity was measured with electronic current velocity meter and discharge was measured with the help of triangular weir at the end of flume and also by equation

\[ Q = AV \]

Here q is discharge in meter/ cubic sec, A is cross sectional area, V is velocity in metre/ sec. Scale down model of 1:50 of bridge # 30 was built, 2 piers with 4 piles (0.393cm) each and with exact same river bed material (type) in flume. Experiments were performed on one of the four effected spans out of twelve spans of b#30. The bridge setup in flume was built at a distance of 3m from water inlet so that turbulent effect due to entering water does not affect actual study area (turbulence affect is generally up to 2m), this also resulted in uniform water flow and water profile. River bed material was filled in flume up to height of 0.2m and up to length of 15m and at the end of downstream soil material stone blocks were placed to retain material. The setup is shown in figure 3.
3.3. Test:
In each experiment water was allowed to run for 24hrs and at the end of experiment water was drained off very carefully so that flume bed couldn’t be disturbed. Scouring was measured both during live water and at the end of complete water drainage with point gauge (with +/-0.5mm error). Experiments were conducted under clear water conditions.

3.4. Remedial measure set-up:
A weir (fig 4) and baffle walls were also provided separately at downstream of piles to study as remedial measures. Weir was provided at a distance of 2m from piles while 3 baffle walls were provided at a distance of 0.30m from piles and with spacing of 0.30m.

4. Results and Discussion:
The following are the results observed in the established laboratory model of the bridge number 30;

- After conducting a series of experiments in hydraulic flume at different discharges from as low as 0.03675cumecs to as high as .060192cumecs, it was observed that live water scouring occurs at the very early stage and at very high discharges i.e. 0.03675Cumecs and above. Clear water stage or equilibrium stage was achieved at time intervals as shown in (Fig.5) against each discharge.

- After conducting 10 experiments general scouring in bed was monitored and measured which was very minimal as shown in (Fig.6) against each discharge. However, after complete drainage of water, heavy scouring was observed at downstream of bridge model starting from 30.48 cm from piles and extending up to end of sand bed in the form of deep channel (Fig 7) each time pattern of channel formed was different.
The general scouring that occurred at downstream of model was nearly in same pattern as of original bridge (Fig 8). It was observed that scouring occurring at the time of draining off of water was more than live water scouring and same is the condition of harrow river flow at the downstream of Khanpur dam. Water flows through spillways of Khanpur dam only in rainy and high flood season and is main cause of general scour of channel bed.

In order to reduce effects of scouring, scale down models of a baffle walls and weir were provided at different distances from piles and results were obtained. Baffle wall was not suitable due to its low height and heavy scouring occurs during experiments at upstream, downstream and sides of baffle walls.

A weir at downstream show magnificent results and no further scouring was noted after piles were submerged initially there was live water scour but that was minimized with the lapse of time. After each experiment on weir water was allowed to drain off very carefully i.e. 3 days and very minute general and local scouring occurred that was 3mm to 4mm throughout the bed.

5. Conclusion:
Based on the laboratory experiments, this study after conducting 15 different experiments of different discharges concludes following

- Live bed scouring is higher for higher discharges.
- Scouring is higher at the time of draining off of water than live scouring of water.
- Downstream weir is beneficial for scour reduction even under high floods while baffle walls were of no importance.

6. Recommendations:
Provision of downstream weir narrows down scope of scouring in case of heavy flooding in inundation canal instead of baffle walls or any other measure as evident from failure of protection measures already provided in years 2000 and 2007. A storage weir construction at the site of bridge number 30 on Harrow River is recommended as best possible measure.

7. References:
[1] Mohammed, T. A., Noor, M. J. M. M., Ghazali, A. H., Yusuf, B., and Saed, K. (2007). Physical modeling of local scouring around bridge piers in erodable bed. Journal of King Saud University-Engineering Sciences, 19(2), 195-206.
[2] Farooq, R. and Ghumman, A. R. (2019). Impact assessment of pier shape and modifications on
scouring around bridge pier. Water, 11(9), 1761.

[3] Melville, B. W., and Coleman, S. E. (2000). Bridge scour. Water Resources Publication.

[4] Wang, Lu, et al. Effects of a downstream submerged weir on local scour at bridge piers. Journal of Hydro-environment Research 20 (2018): 101-109.