International Journal of Scientific & Engineering Research Volume 10, Issue 2, February-2019 1264
ISSN 2229-5518

# EXPERIMENTAL STUDY OF SCOUR AT ABUTMENTS OF RIVER KABUL BRIDGES IN PAKISTAN

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**Abstract:** *The focal problem for river Kabul bridges in Pakistan during maximum flood is scour at bridge pier and abutments causing its collapse and/or isolation from approach road. This will result in bridge failure, human loss, damage to properties and traffic disruption. Keeping in view the problems caused by bridge failure, it is important to check the vulnerability of abutments for failure due to scouring. Therefore, in this study the abutments of two vulnerable bridges i.e. Hajizai Bridge and Pushtoon Garhi Bridge on river Kabul are analyzed for scour depth measurement using small scale modeling in the laboratory. are selected for small scale study*. *The experiments were carried out for spill-through abutment of Hajizai Bridge and wing-wall abutment of Pushtoon Garhi Bridge. The results showed that the scour occurs in front as well as at both sides of the abutments in both cases. Contours maps are drawn to show the variation of scour depth around the abutments in both cases.*

***Keywords***: *river Kabul, spill-through abutment, wing-wall abutment, scour critical, model channel.*

## I. INTRODUCTION

The river Kabul is historical significance for Pakistan its total length is about 700km out of which 140km in Pakistan. River Kabul is started from Hindu Kush Mountains and finally end into Indus River near Attock Pakistan. The major tributaries in Afghanistan are Logar, Panjshir, Kunar and Alingar while in Pakistan river Swat, Budni nullah, river Jindi and Bara stream. All constructed bridges on river Kabul are mostly pre-cast girders bridges and two are steel truss bridges which connect various districts of Khyber Pakhtunkhwa province of Pakistan as shown in figure 01 below.


***Figure 01 Bridges on river Kabul in Khyber Pakhtunkhwa Pakistan***

Abutment is structure upon which the ends of bridges rest, to distribute the loads from bridge ends to ground, retain the material of embankment and provides access to vehicular and pedestrian to the bridge. Mainly there are two types of abutment one is spill-through (open) abutment and second is wing-wall (closed) abutment. The waterway bridge abutment which is exposed to direct flow of water will scour during normal flow or flood.
The lowering of the river bed at bridge abutment due to flowing water is called bridge abutment scour. (FDOT Bridge Scour Manual, 2005). Bridge scour is the result of the erosive action of flowing water, excavating and carrying away material from the bed and banks of streams and from around the piers and abutments of bridges. (HEC-18, 2001)

Scour at bridge abutment is dynamic phenomenon and depend on various factors like flow depth, angle of attack shape of abutment, dimension of abutment, and bed sediment. Usually three types of scour occur at bridge abutments which are aggradations or degradation, contraction scour and local scour.
The scouring of bridge abutment occurs at the following locations/regions due to flow field, abutment layout and erosion of material including 1) Scour occur at main channel close to the abutment of bridge, 2) At some distance to downstream of the abutment of bridge 3) Around the abutment of bridge and 4) Scour occur at the approach embankment at some distance from abutment.
Scour at the above four locations /regions occurred at different rates and can varies up to extreme depth, in accordance with flow-field and soil conditions and finally at each location the scour create slope instability of adjacent embankment as shown in Figure 2 below.

***Figure 02: Extreme scour at bridge abutment of Sardaryab Bridge on river Kabul during flood, 2010***



The figure 02 shows the importance of abutment scour study of river Kabul birdges. The isolation of bridges abutment from approach roads were observed during flood of 2010 in Pakistan. In this research study, experimental study was carried out to measure the abutment scour depth for two bridges on Kabul River. The aim was to find the scour depth as well as its location.

## II. LITERATURE REVIEW

A research was carried out on bridges failures in USA between 1989-2000 and they were found that about 500 bridges failed due to scouring at piers and abutments. (Wardhana & Hadipriono, 2003)
A study was carried out for U.S Federal Highway Administration on failures of bridges and it was concluded that 383 bridges failures occurred out of which 25% failed due to pier damage while 72% due to abutment damage during flood. (Richardson EV & Abed L., 1993)
A survey was carried in New Zealand during the period of 1960-1984 in which 108 bridge failures studied and found that out these 29 bridges failed due to scouring at abutment. It was also investigate that 70% expenditure was due to abutment scour failure. (Melville, 1992).
Study carried out for 488,755 stream and river bridges in U.S and total cost of scouring was calculated and estimated at $30 million. (Lagesse et al., 1997).
The fluctuating pressure variation are induced by the flow split-up at abutments cause seepage and owing to seepage forces the sediment particles under foundation escape and as result scouring occurred. (Hagerty & Parola, 1992)
The scour around at bridge abutment is complicated nature phenomenon and because of complexity the most of study has base on physical modeling therefore in this regard some of major contribution are Reza Mohammad pour, Nor Azazi Zakaria, Aminuddin Ab. Ghani and Thamer Ahmed Mohammed Ali (2017), Pezhman Taherei, Ghazvinei, Junaidah Ariffin, Jazuri Abdullah and Thamer Ahmed Mohamed (2014), Mokhles M.Abou-seida, Gamal H.Elsaeed, Tarek.M.Mostafa & Flzahry F. Elzahry (2012), Yanmaz AM and Kose O (2007), Barbhuiya and Dey (2004), Melville and Coleman (2000), Breusers and Raudkivi (1991), Melville and Sutherland (1988), Raudkivi (1986), Raudkivi and Ettema (1983), Ettema (1980), Gill (1972), Laursen (1963).

## III. RESEARCH METHODOLOGY

After carrying out detail survey of all constructed bridges on river Kabul and its tributaries from Warsak Dam to Indus river, the spill-through abutment of Hajizai bridge and wing-wall abutment of Pushtoon Garhi bridge were selected because of different type of river bed material.

### 3.1. DESCRIPTION OF HAJIZAI BRIDGE

Hajizai Bridge is located on Naguman Shabqadar road which link Peshawar to Charsadda and Mohmand Districts of Khyber Pakhtunkhwa, Pakistan. Total length of bridge is 250m having 10 spans 25m each. The abutment of this bridge is spill-through abutment having transom with back walls and wing walls which is supported on 1.2m diameter four number in single row piles each having length of 25m. The detail dimensions and levels given in below drawings of abutments.
Consideration of the channel's size a geometrically undistorted model of scale 1:40 was selected for model construction of abutment.

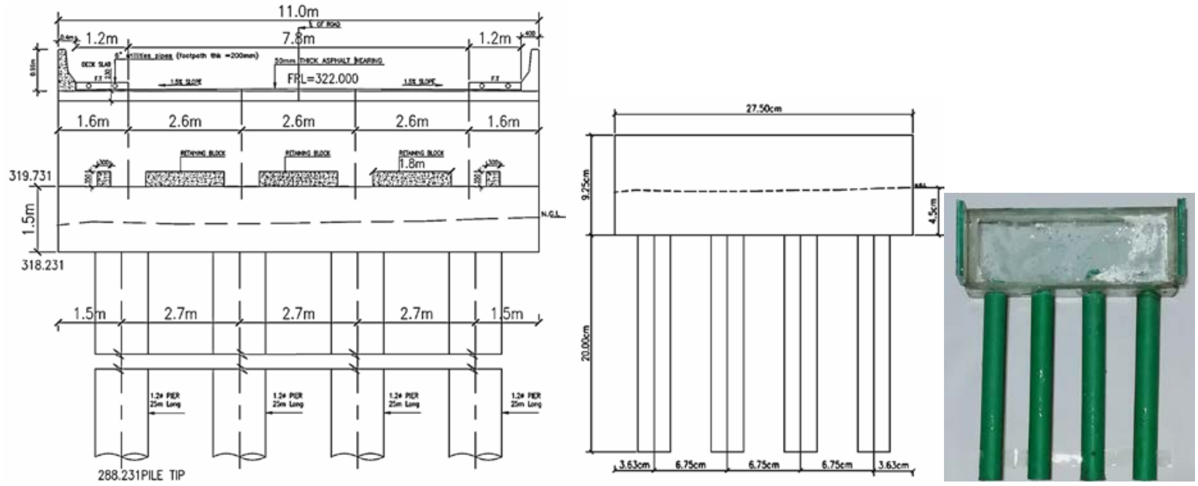


*Figure 03: Hajizai Bridge Spill-through Abutment Prototype & Model Detail and Model Picture*



### 3.2. Discharge for Hajizai Bridge

Discharge data was collected from Irrigation Department Peshawar KP Pakistan for experimental scour estimation and flood record and the data was reduced according to scale 1:40 and discharge 8.0 cusec of flood on July, 2011 was considered for Haji Zai bridge abutment experiment.

$$Q_{model} = Q_{prototype}\ (L_r)^{5/2}$$
$$Q_{model} = Q_{prototype}\ (1/40)^{5/2}$$

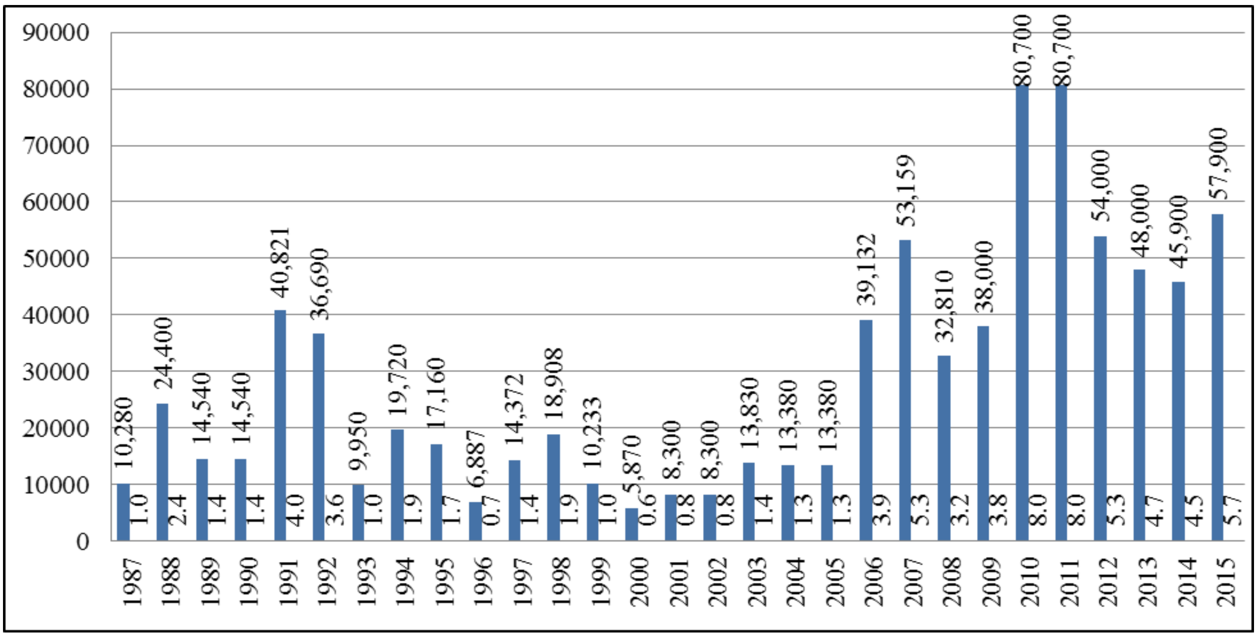

*Figure 04: Actual and Reduce Scale Discharge Data for Hajizai Bridge*

### 3.3. River Bed Material for Hajizai Bridge

The river bed material at Hajizai Bridge contained 40% sand and 60% gravel of maximum size 15cm. The following grain size distribution curve give the exact idea regarding the gradation of the material.

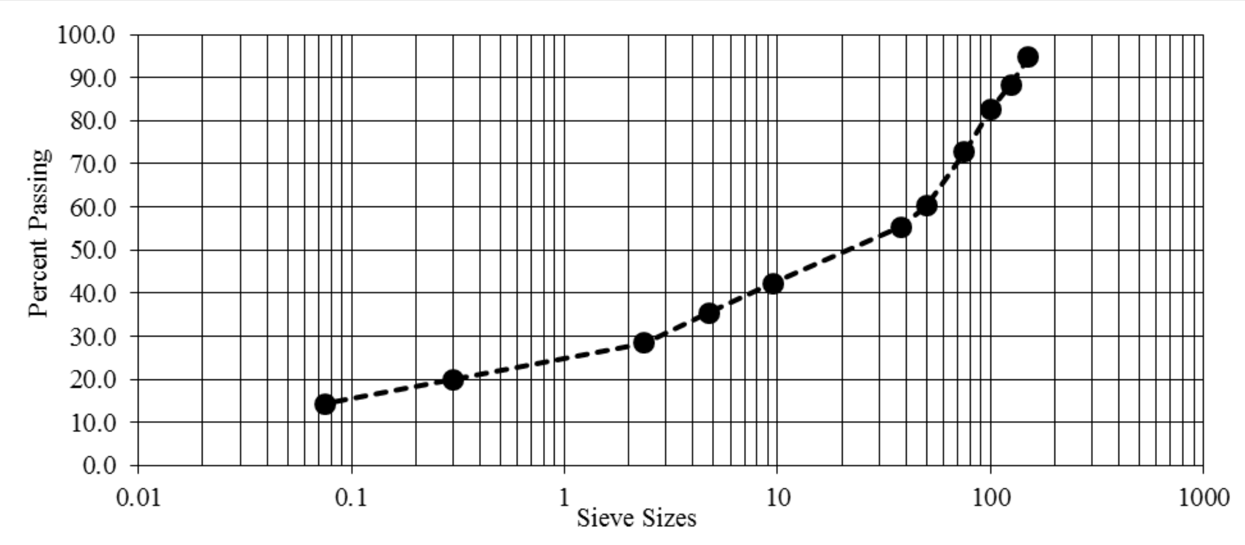


***Figure 05: Actual River Bed Material Distribution Curve***

The material of river bed was reduced according to selected scale 1:40 and grain size distribution curve plotted as shown below. The reduce size gravel (maximum size 4.75mm) was mixed with fine sand for preparation of required river bed material.



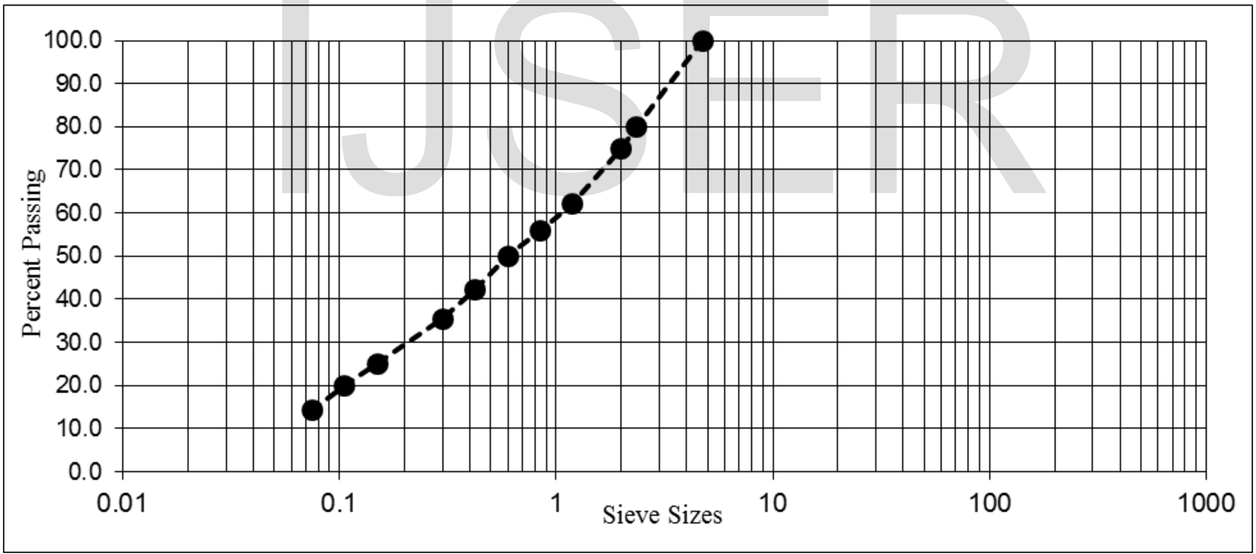


***Figure 06:Reduce Size River Bed Material Distribution Curve***

### 3.4. DESCRIPTION OF PUSHTOON GARHI BRIDGE

This bridge is short link between Pabbi District Nowshera and Charsadda also provide all weather access to numerous villages in area of District Peshawar, Nowshera, Charsadda and Mardan of KP Pakistan. Total length of bridge is 420m having 14 spans 30m each. Pushtoon Garhi Bridge abutment is wing wall abutment having pile cap, abutment wall with counterfort walls, transom, back walls and wing walls which is supported on ten 25m deep double rows 0.75m diameter piles.

Consideration of the channel's size a geometrically undistorted model of scale 1:40 was selected for model construction of abutment.

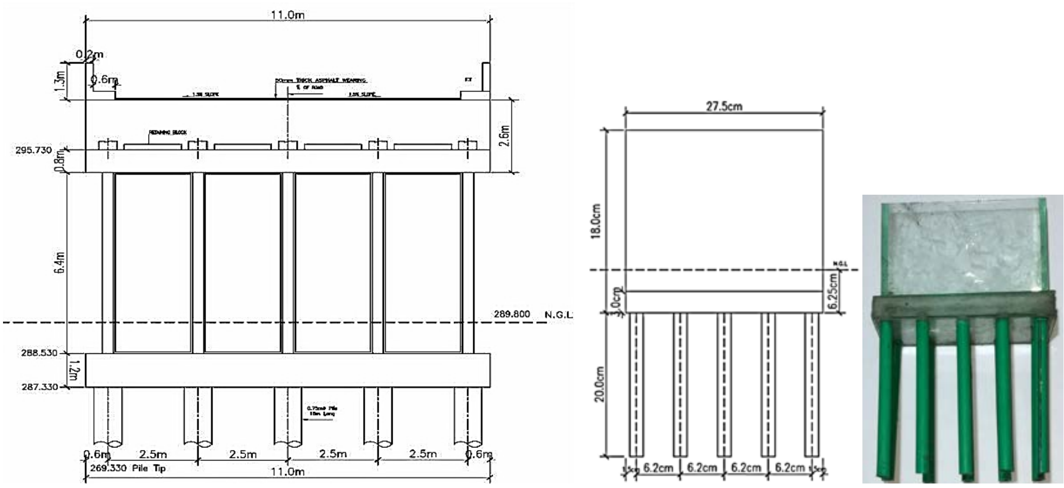


*Figure 07: Pushtoon Garhi Bridge Wing-wall Abutment Prototype & Model Detail and Model Picture*

### 3.5. Discharge for Pushtoon Garhi Bridge

Discharge data was collected for Irrigation Department Peshawar KP Pakistan for experimental scour estimation and flood record the data was reduced according scale 1:40 and discharge 8.0 cusec of flood on July, 2013 was considered for Pushtoon Garhi bridge abutment experiment.

$$Q_{model} = Q_{prototype}\,(L_r)^{5/2}$$
$$Q_{model} = Q_{prototype}\,(1/40)^{5/2}$$

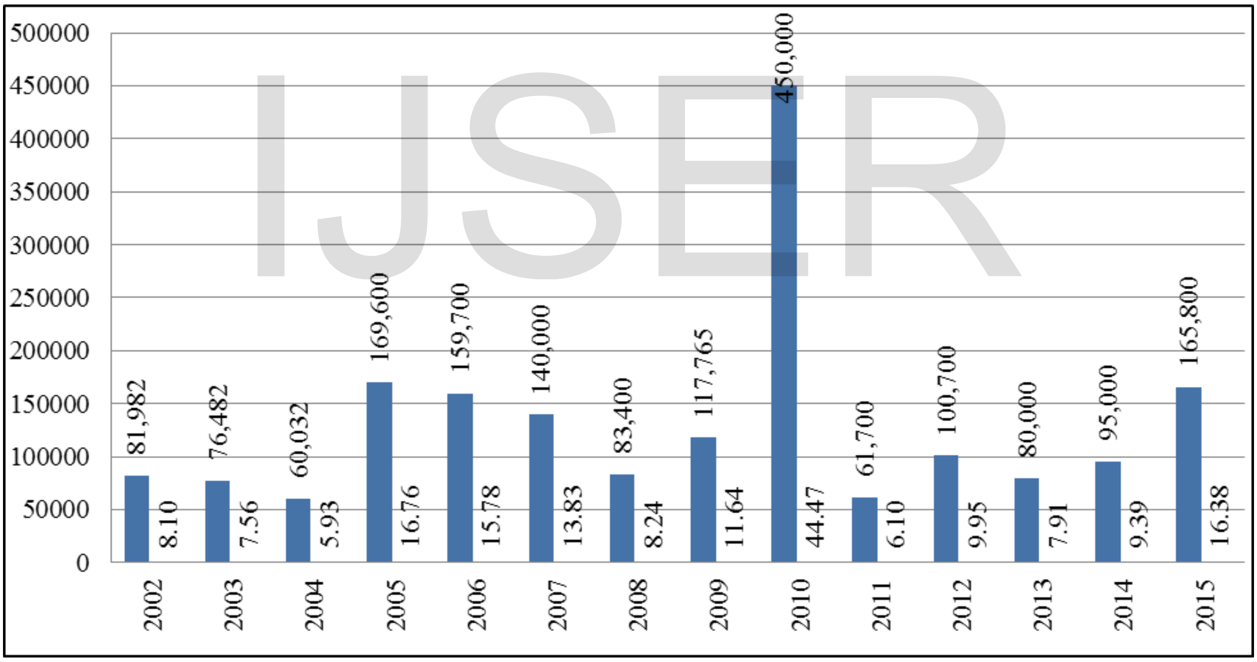



*Figure 08: Actual and Reduce Scale Discharge Data for Pushtoon Garhi Bridge*

### 3.6. River Bed material at Pushtoon Garhi Bridge

The river bed material at Pushtoon Garhi Bridge is fine sand and for experiment the actual material was collected from bridge site.

### 3.7. Experimental Procedure

A rectangular cross section irrigation channel of size 90cm width and 90cm depth near tributary of river Kabul was chosen for both experiments so that to use river Kabul water flow. A straight portion of channel for test section was selected at adequate distance (40m) from diversion gate to obtained uniform flow of water. For Hajizai Bridge experiment the prepared reduce size material (sandy gravel) while for Pushtoon Garhi Bridge experiment the collected

ISSN 2229-5518
river bed material from bridge site (fine sand) was recess in 30cm thickness at test section plus ample length at upstream and downstream and leveled with wooden screed in full width of channel respectively.


***Figure 09: Model Channel, Discharge Confirmation, Abutment Set-out and flow of water in Model Channel***

The glass model of bridge abutment was installed at one side of the channel at test section. Prior the flow levels of bed material were taken with help of point gauge on grid with mesh 12.5cm x 20cm at test section and noted. The water was released slowly from inlet of proposed channel up to confirmed 8.0 Cusec discharge (8.0 Cusec equal to August, 2010 flood for Hajizai and July, 2013 flood for Pushtoon Garhi Bridge). The flow was run for 90 minutes to ensure that scour had reached the equilibrium depth. After 90 minutes flow, the water was stopped from diversion point and all water was drained slowly without disturbing the scour topography. The bed topography was measured with point gauge on same grid with mesh 12.50cm x 20cm at test section and noted.

***Figure 10: Showing Scour Holes at Wing-wall Abutment of Pushtoon Garhi and at Spill-through Abutment of Haji Bridge***

## VI. RESULTS AND DISCUSSION

The abutments of both bridges were set out at edge of channel and embedded in corresponding river bed up to maximum flood level. Reading taken at mesh of grid 12.50cm across the channel and 20.00cm along the channel before and after the flow and scour depth was calculated from both vertical readings difference and tabulated.

### 4.1. RESULTS OF HAJIZAI BRIDGE SPILL-THROUGH ABUTMENT

The observation data of experiment for Hajizai bridge spill-through abutment obtained and noted in table 01 showing maximum scouring near abutment.

***Table 01: Observation Data of Hajizai Bridge Spill-through Abutment Experiment***

| 0 | 12.50 | 25.40 | 37.50 | 50.80 | 63.50 | 76.00 | 88.50 |
|---|---|---|---|---|---|---|---|
| 20 | 6.30 | 6.50 | 6.80 | 6.10 | 7.00 | 7.90 | 8.8 |
| 40 | 6.60 | 7.10 | 7.10 | 7.20 | 7.20 | 7.20 | 7.2 |
| 60 | 6.90 | 7.50 | 7.00 | 7.50 | 7.30 | 7.10 | 6.9 |
| 80 | 7.00 | 8.00 | 7.50 | 7.30 | 7.80 | 8.30 | 8.8 |
| 100 | 7.20 | 8.20 | 7.60 | 7.40 | 8.20 | 9.00 | 9.8 |
| 110 | 7.30 | 7.80 | 7.80 | 7.50 | 8.50 | 9.90 | 10.6 |
| 120 | 7.10 | 7.30 | 7.60 | 7.20 | 8.50 | 9.80 | 10.5 |
| 140 | 7.00 | 6.80 | 7.10 | 7.50 | 8.10 | 8.70 | 9.3 |
| 160 | 6.90 | 6.80 | 6.30 | 6.80 | 7.50 | 8.20 | 8.9 |
| 180 | 6.80 | 6.10 | 6.00 | 6.30 | 6.70 | 7.10 | 7.5 |
| 200 | 6.30 | 5.90 | 5.60 | 5.90 | 6.30 | 6.70 | 7.1 |
| 220 | 6.00 | 5.80 | 5.50 | 5.80 | 6.00 | 6.20 | 6.4 |

Scour contour map was plotted (figure 11) in surfer software showing the scour at front and around the abutment.

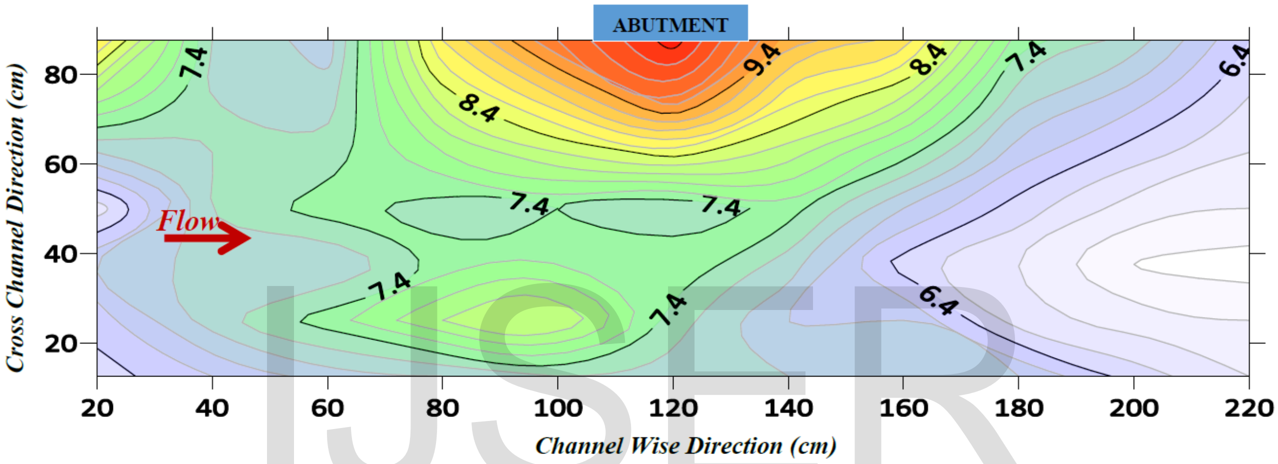


*Figure 11: Scour Contour Map for Hajizai Bridge Spill-through Abutment*

The experiment was revealed that all piles of spill-through abutment exposed up to maximum limit which need some scour protection countermeasures at front of abutment as well as at upstream and downstream of spill-through abutment. Therefore, it was concluded that spill-through abutment should be constructed at sufficient distance behind from flood plan plus scour countermeasures must also provide at front and around the abutment.

### 4.1. RESULTS OF PUSHTOON GARHI BRIDGE WING-WALL ABUTMENT

The observation data of experiment for Pushtoon Garhi bridge wing-wall abutment obtained and noted in table 02 showing maximum scouring near abutment.

*Table 02: Observation Data of Pushtoon Garhi Bridge Wing-Wall Abutment Experiment*

| 0 | 12.50 | 25.40 | 37.50 | 50.80 | 63.50 | 76.00 | 88.50 |
|---|---|---|---|---|---|---|---|
| 20 | 8.10 | 8.50 | 7.90 | 8.20 | 8.40 | 9.30 | 9.10 |
| 40 | 8.40 | 9.50 | 8.30 | 8.50 | 9.20 | 9.60 | 9.50 |
| 60 | 8.50 | 9.60 | 8.10 | 8.80 | 9.80 | 10.20 | 10.30 |
| 80 | 9.20 | 9.30 | 8.30 | 9.10 | 9.50 | 10.60 | 10.70 |
| 100 | 9.80 | 9.30 | 9.10 | 9.50 | 10.50 | 11.60 | 11.80 |
| 110 | 10.00 | 9.40 | 9.80 | 9.80 | 11.20 | 12.20 | 12.50 |
| 120 | 10.20 | 9.50 | 10.00 | 9.40 | 11.50 | 12.30 | 12.60 |
| 140 | 11.00 | 10.00 | 11.20 | 9.60 | 11.20 | 11.80 | 12.00 |
| 160 | 10.20 | 9.50 | 9.10 | 9.30 | 10.30 | 10.60 | 10.50 |
| 180 | 9.00 | 8.80 | 8.00 | 8.10 | 9.00 | 10.00 | 9.50 |
| 200 | 8.10 | 8.20 | 7.80 | 8.40 | 8.00 | 9.00 | 9.10 |
| 220 | 7.80 | 7.80 | 7.30 | 8.10 | 7.80 | 8.80 | 8.50 |

Scour contour map was plotted (figure 12) in surfer software showing the scour around the pile cap of abutment.

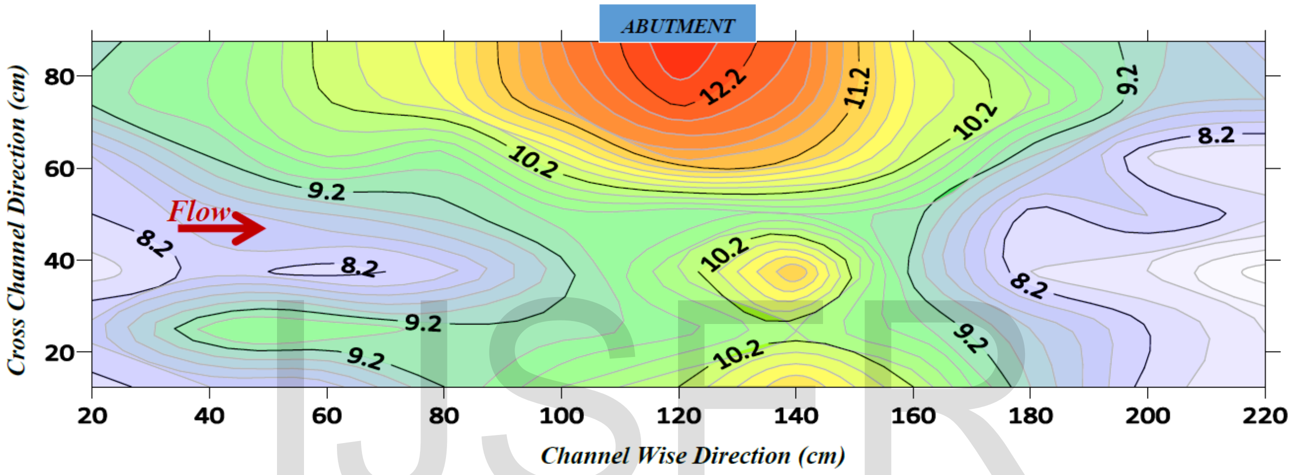


*Figure 12: Scour Contour Map for Pushtoon Garhi Bridge Wing-wall Abutment*



The experiment was revealed that the piles beneath the pile cap exposed up to some extend which can be avoided by increasing the depth of pile cap under natural surface level of river. While for upstream and downstream protection some countermeasures are required.

### 4.3. Comparison

The comparison of scouring at both types of abutment carried out through graphs along length of channel and width of channel. Almost similar results were obtained maximum scour observed near both abutments as compared to scour at far side of channel. Lesser scour depth was observed in gravel river bed material as compared to fine sand river material.

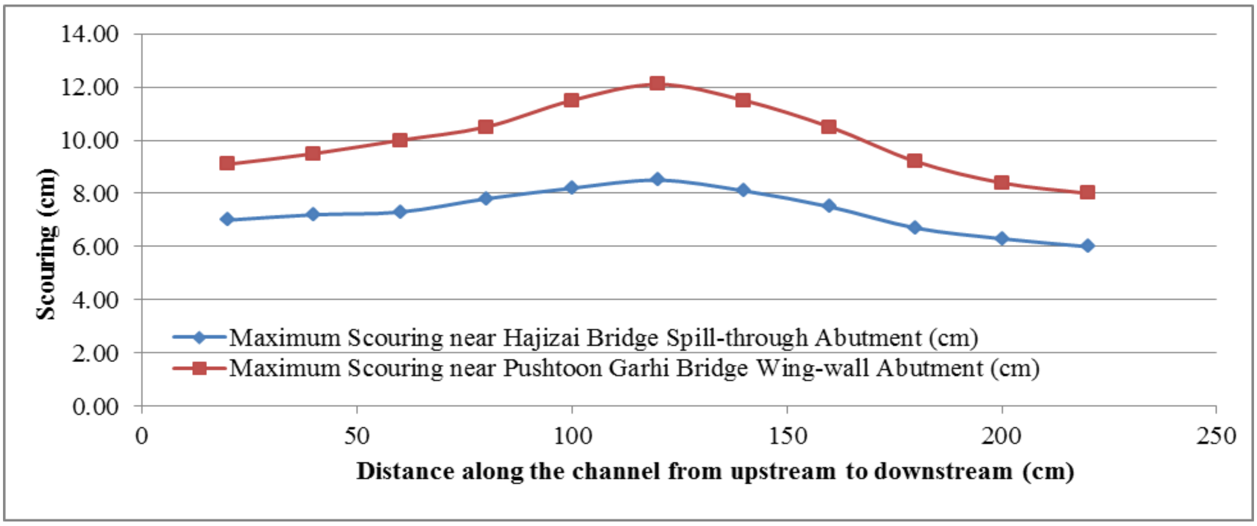


***Figure 13. Comparsion of Scouring at Spill-through Abutment of Hajizai Bridge and Wing-wall Abutment of Pushtoon Garhi Bridge along the Channel***

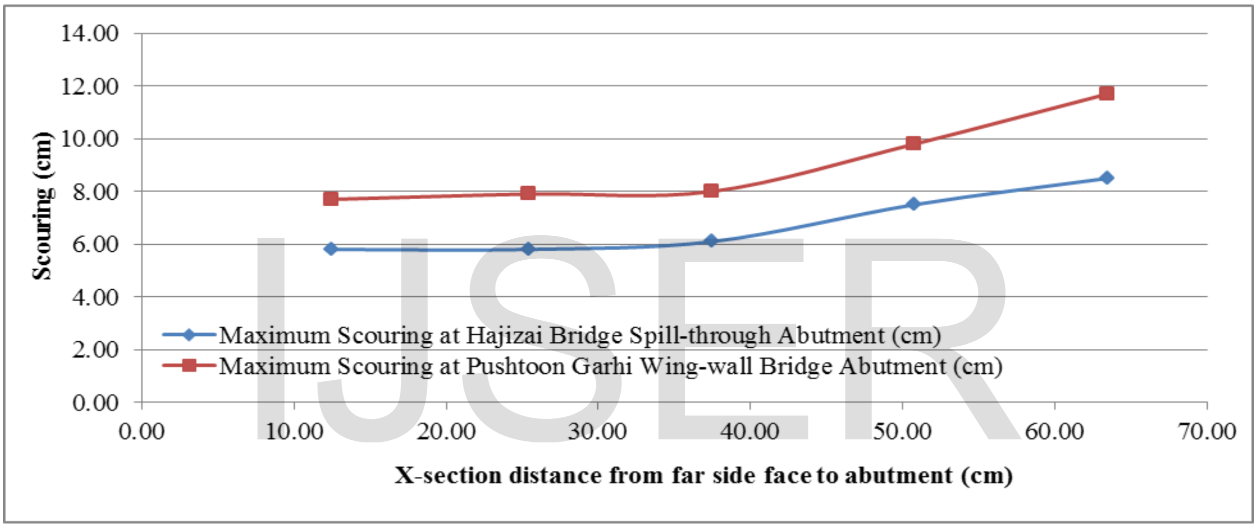




***Figure 14. Comparsion of Scouring at Spill-through Abutment of Hajizai Bridge and Wing-wall Abutment of Pushtoon Garhi Bridge Across the Channel***

## V. CONCLUSION AND RECOMMENDATION

It was concluded after this experimental study that scour was occurred at main channel closed to abutment, at some distance to downstream of abutment, around the abutment and behind the abutment moreover all piles of abutment were exposed after scoured. Therefore, on the basis of this investigation the following recommendations were proposed for river Kabul Bridges Abutments;

1. Properly design piles foundation with accurate depth of pile cap should be recommended for abutments of river Kabul Bridges.
2. The spill-through abutment should be constructed at sufficient distance behind the flood plan.
3. For protection of both types of abutment flexible type scour countermeasures (like gabions wall with apron etc.) should be constructed at front, upstream and downstream of abutment.

Furthermore, comprehensive experimental study is required for commonly use countermeasures for river Kabul bridges which are rubble concrete retaining wall, random stone masonry retaining wall, grouted stone pitching and gabions wall with apron.

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