

A Study on the Effect of Spacing between Permeable Spurs in Flow Diversion from near Bank within the Straight reach of an Experimental Field Channel

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Abstract --Riverbank erosion and channel instability are among the most critical challenges in alluvial river systems, posing significant threats to infrastructure, agricultural land, and human settlements worldwide. The rivers of the north-eastern region of India predominantly originate in the Himalayan foothills and are characterized by exceptionally high sediment loads throughout the year. Upon entering the Assam Valley, these rivers experience a substantial reduction in channel slope, resulting in a corresponding decrease in flow velocity and sediment transport capacity. Consequently, large quantities of sediment are deposited within the channel, leading to progressive bed aggradation, reduction of the effective flow area, and the development of mid-channel bars. During the monsoon season, when the rivers convey maximum discharges, the confined flow is often directed towards the riverbanks, causing severe bank erosion and channel instability.

To mitigate these adverse impacts, the implementation of efficient river-training measures is of paramount importance. Among the various erosion-control techniques adopted in the region, porcupine screens have been extensively utilized owing to their relatively low cost, permeability, and ease of construction. However, the performance of such installations has frequently been inconsistent, largely due to the absence of scientifically established design guidelines and standardized layout configurations. Furthermore, the existing arrangements of porcupine structures are generally not tailored to the hydraulic and geometric characteristics of the river reaches where they are deployed, thereby limiting their effectiveness.

In this context, the present investigation was undertaken to systematically evaluate the hydraulic performance of different porcupine configurations with respect to their ability to divert flow from the near-bank region towards the central portion of the channel. Scaled physical models of porcupine structures were designed based on channel geometry and flow conditions and subsequently installed in an experimental field channel.

The effectiveness of each configuration was assessed through detailed velocity measurements acquired using an Acoustic Doppler Velocimeter (ADV). Flow diversion characteristics were quantified by analyzing the variation of velocity distribution across the channel section, particularly between the near-bank and mid-channel regions. Based on the observed hydraulic responses, the relative performance of the porcupine models was compared, and the most effective configurations were identified under different submergence conditions.

Keywords: Porcupine, Erosion Control, Permeable spur, Flow diversion, Bank protection

I. INTRODUCTION

Riverbank and in-stream protection is becoming a necessity in many major rivers of India where scouring of the river bed and bank materials leads to change the river course and thereby flooding and causing losses to lives and properties in the nearby areas. Protection measures like dykes, impermeable spur embankments etc. associates with high labor and material cost. Thus in such reaches of the big Indian rivers it becomes necessary to employ some cost effective measures which are reliable as well as economical. Due to the increase in the demand of such economic measures many researchers have been studying different types of structures to reduce the problem of bed and bank erosion. Nowadays Porcupines have been also installed in many reaches of the big Indian rivers like Brahmaputra, kosi etc. and have yielded fairly good performance in erosion control.

II. MATERIALS USED AND THE METHODOLOGY ADOPTED

A. Materials Description

1. Porcupine

i) Prototype (RCC Porcupine)

RCC porcupines (Fig 1) consists of six members made-up of RCC, which are joined with the help of the iron nuts and bolts. Depending upon the field requirements the length of each members may vary from 2m to 3m and cross section is 15cm×15cm or 10cm x 10cm. Reinforcement is usually given using 4 numbers of MS bars of 6 mm diameter, with stirrups at 15 cm c/c.



Fig 1: RCC Porcupines laid in Majuli, Assam

ii) Model

The porcupine models used in this study are prepared in reducing scale (Fig 2) to match the dimensions of the field channel as per the guidelines of CWC manual 2012. The models are prepared by bamboo sticks of size 5cm in length and 0.5 cm in thickness which were glued together. Extended lengths of 3cm for each member of the model are kept for embedding them into the simulated river bed in the field channel. Photograph of the model is shown below.

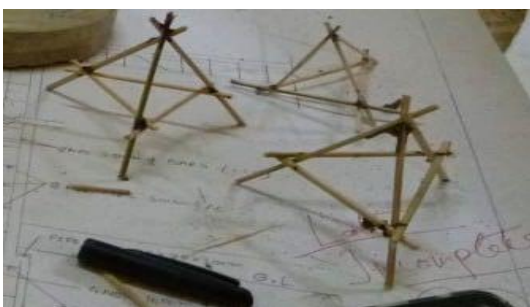


Fig 2: Prepared porcupine models

B. Bed material

The bed material was collected from river Bhogdoi, Jorhat. After collecting the river bed material sample, they were air dried for evaluating the particle size distribution and the material was found to be poorly graded fine sand. The bed of the field channel was filled with this collected sample up to a depth of 15 cm from the cut surface. This depth has

been selected on the basis of trial runs in the channel without porcupine models with different discharges and observing the scouring level for such runs. A channel bed with a minimum thickness of 15 cm has been found to withstand significant scouring and subsequent exposure of the cut surface of the channel under any trial run.

C. The Field Channel

All the experiments for this study were carried out in a field channel that was developed inside the campus of Jorhat Engineering College, Assam. The field channel that was developed for the study is about 27.0 m long, 1.0 m wide and about 0.4m deep. Out of this 0.4m total depth of the channel, 0.2 m were kept available for flow, after preparing the channel bed by filling up the bottom 0.15m with collected bed materials and considering a free board of 0.05m. Two 15 HP pumps were installed nearby to collect water from the JEC lake and feed the same into the experimental channel. The water from the pumps was first collected into a chamber (Fig 4). The water released from the collecting chamber then goes through some energy dissipaters (steps) for reducing the turbulence of the flow before entering the main channel. A foot valve was installed at the bottom of the channel near its u/s face to regulate the quantity of water to be fed to the channel in order to maintain different depths of flow inside it. The d/s of the channel is again fed to the JEC lake to complete the circle of flow. A steel trolley was installed to support the ADV; above the channel on the side walls (with rails on their tops) that were constructed on both the sides of the channel, as shown in Fig 5. A view of the prepared field channel is also shown in Fig 3.



Fig 3: The prepared field channel with the installed porcupine models



Fig 4: The collecting chamber that receives the water from the pump



Fig 5: The ADV with probe over the steel trolley installed in the channel

D. Acoustic Doppler Velocimeter

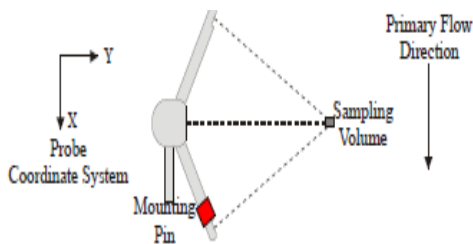


Fig 6: ADV probe orientation to stream flow

An Acoustics Doppler Velocimeter works on the principle of capturing change in frequency in acoustic waves. The ADV sends out a beam of acoustic waves at a fixed frequency from a transmitter probe. These waves bounce off a moving particulate matter in water and the three receiving probes listen to change in frequency of the returned waves. The ADV then calculates velocities in x, y and z direction.

III. EXPERIMENTAL PROCEDURE

Before every experimental run, the channel bed was levelled and flow was introduced for a particular depth of flow. The required depth of flow for maintaining different

submergence ratios was achieved by trying out different pump and valve combinations. Before installing the porcupine models into the channel, free run was conducted for about 20 minutes and the water was allowed to discharge completely after closure of the feed. After this free run; the porcupine models of required combinations were installed and flow was again introduced by maintaining the depths required to achieve the desired submergence Ratios. As the flow would get diverted from the near bank towards the middle of the channel by the spurs, the flow velocity datas were taken at the middle of the channel using the ADV, at upstream and downstream of every porcupine spur installed within the screen and the change in velocity is calculated after the flow crosses each screen. In case of a diversion of flow an increase in velocity will be seen in the mid channel as more quantity of water will pass through the same cross section.

After taking the flow velocity observations, the pumps were shut down and water was again allowed to discharge completely out of the channel. In this manner several trials were conducted using porcupine screens comprising of 3, 4 and 5 no.s of spurs spaced apart c/c by 3, 4 and 5 times their length. Submergence ratios of 1.7, 2.0 and 2.5 for each of the screen models were found to be achievable with the available set-up of feeding pumps and foot valve combinations. The models used are listed below:

Table 1: Different models used

Model no	Combinations	Submergence ratio
1	3 spur with 3L spacing	1.7
	3 spur with 3L spacing	2.0
	3 spur with 3L spacing	2.5
2	3 spur with 4L spacing	1.7
	3 spur with 4L spacing	2.0
	3 spur with 4L spacing	2.5
3	3 spur with 5L spacing	1.7
	3 spur with 5L spacing	2.0
	3 spur with 5L spacing	2.5
4	4spur with 3L spacing	1.7
	4spur with 3L spacing	2.0
	4spur with 3L spacing	2.5

5	4spur with 4L spacing	1.7
	4spur with 4L spacing	2.0
	4spur with 4L spacing	2.5
6	4spur with 5L spacing	1.7
	4spur with 5L spacing	2.0
	4spur with 5L spacing	2.5
7	5spur with 3L spacing	1.7
	5spur with 3L spacing	2.0
	5spur with 3L spacing	2.5
8	5spur with 4L spacing	1.7
	5spur with 4L spacing	2.0
	5spur with 4L spacing	2.5
9	5spur with 5L spacing	1.7
	5spur with 5L spacing	2.0
	5spur with 5L spacing	2.5

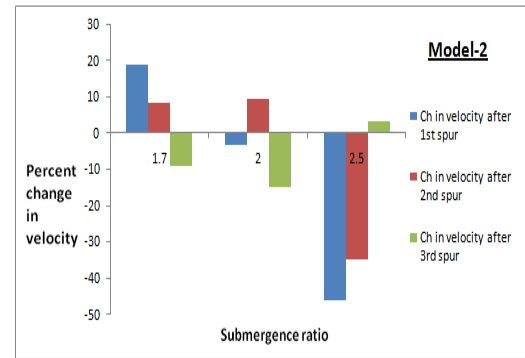


Fig 8: Change in velocity in mid channel due to installation of Model 2 against different submergence ratios

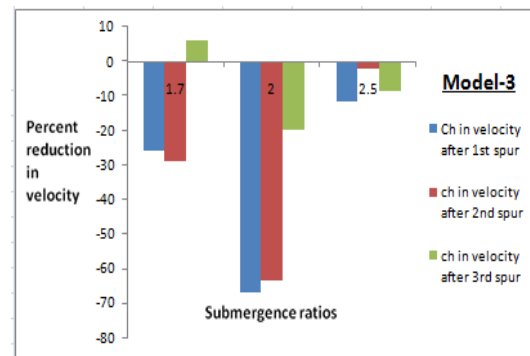


Fig 9: Change in velocity in mid channel due to installation of Model 3 against different submergence ratios

Where, L=Length of spur

IV. RESULTS AND DISCUSSIONS

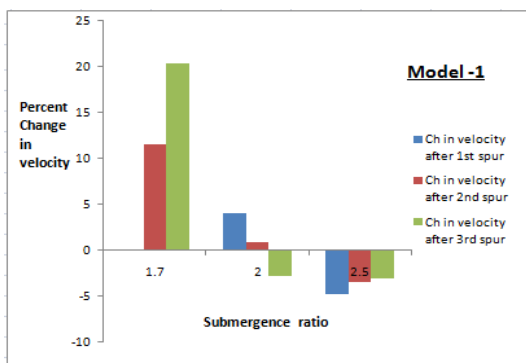


Fig 7: Change in velocity in mid channel due to installation of Model 1 against different submergence ratios

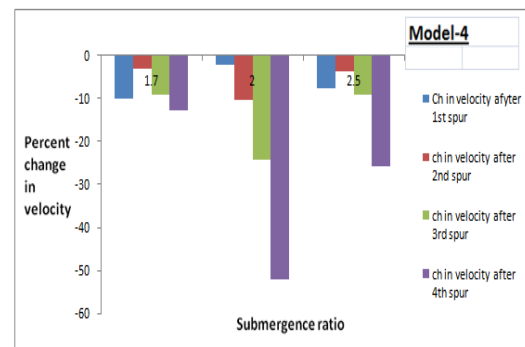


Fig 10: Change in velocity in mid channel due to installation of Model 4 against different submergence ratios

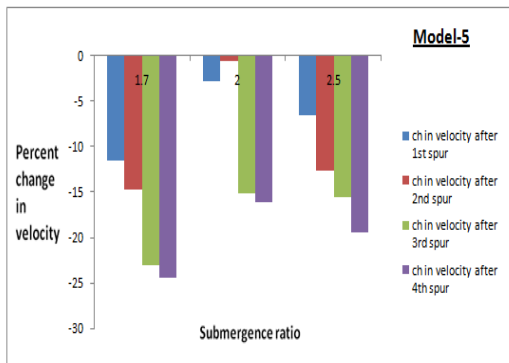


Fig 11: Change in velocity in mid channel due to installation of Model 5 against different submergence ratios

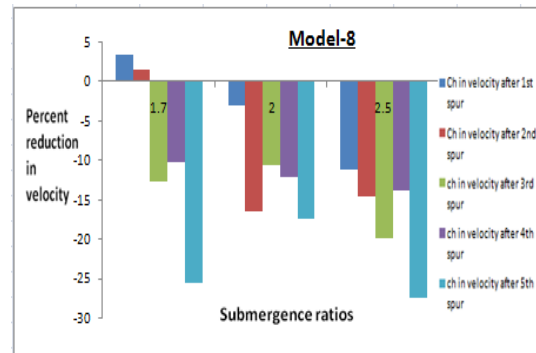


Fig 14: Change in velocity in mid channel due to installation of Model 8 against different submergence ratio.

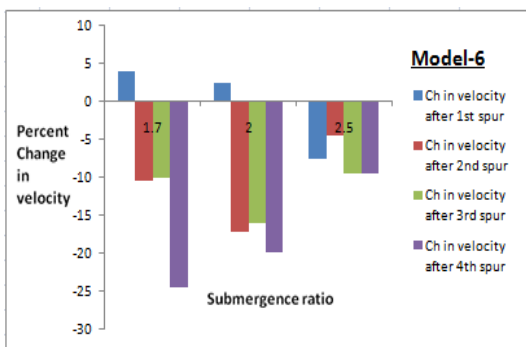


Fig 12: Change in velocity in mid channel due to installation of Model 6 against different submergence ratios

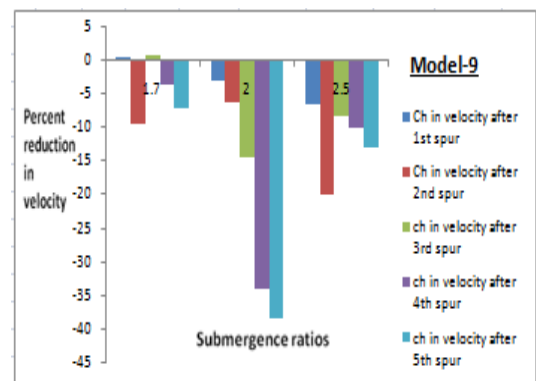


Fig 15: Change in velocity in mid channel due to installation of Model 9 against different submergence ratios

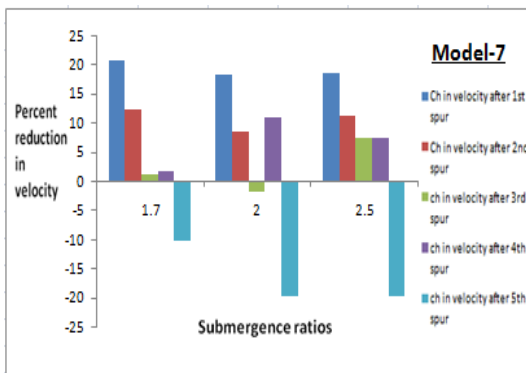


Fig 13: Change in velocity in mid channel due to installation of Model 7 against different submergence ratios

It is seen from the above figures that in cases of model 1,2,3,6,7, 8 and 9 (Figures 7,8,9,12,13,14 and 15) there has been an increase in velocity in the mid channel, which is an indication of the flow getting diverted from the near bank towards the middle of the channel. It is observed that more flow diversion is taking place with lesser submergence ratios and the best performing ratio was found to be 1.70.

It can be observed from the above cases that more flow diversion is seen with lesser spacing and with a spacing of 3L (where L= Length of spur),maximum flow diversion is achieved.

With 20.1% maximum velocity increase model -1 proves to be the most effective incase of overall flow diversion.

Model-3 exhibited the poorest flow diversion performance among all tested configurations. Despite having the largest spacing within its group, it produced predominantly negative velocity changes and recorded the maximum velocity reductions of approximately 66%

V. CONCLUSIONS

The experimental study shows that for a given submergence ratio, flow diversion exhibited an inverse relationship with spur spacing. Closely spaced spurs generated stronger cumulative flow deflection due to greater interaction between successive spur-induced flow fields, resulting in higher velocity enhancement. As spur spacing increased, this interaction weakened, causing a progressive reduction in velocity enhancement and consequently a decline in flow diversion efficiency. The results indicate that excessively large spacing diminishes the collective effectiveness of the spur field by allowing the diverted flow to regain momentum before interacting with downstream spurs.

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