

A Study on The Effect of Number of 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 instability and active channel migration present severe socio-economic threats across major Indian river basins, including the Brahmaputra and Kosi systems. Intense bed and bank scouring frequently alters river courses, triggering catastrophic seasonal flooding, property destruction, and loss of life. While conventional structural interventions—such as stone-pitched dykes and impermeable solid spurs—are hydraulically effective, their widespread implementation is heavily constrained by high material costs, intensive labor demands, and localized secondary scouring.

Consequently, identifying cost-effective, reliable, and ecologically viable river-training alternatives is critical. Recent hydraulic research and field implementations have increasingly focused on permeable structures, specifically Reinforced Cement Concrete (RCC) porcupine systems. Unlike rigid, impermeable embankments that abruptly deflect

high-velocity currents, porcupine screens function as energy dissipators. By allowing partial flow through their open tetrahedral frameworks, they induce controlled micro-turbulence, decrease localized velocity, and accelerate sediment deposition (siltation) along vulnerable bank lines. Field installations in highly dynamic macro-tidal and braided rivers have demonstrated that these permeable configurations offer a highly reliable and economically sustainable solution for long-term 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 Rohmoriam, Dibrugarh, Assam

(Source: <https://waterresources.assam.gov.in>)

ii) Mo

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.

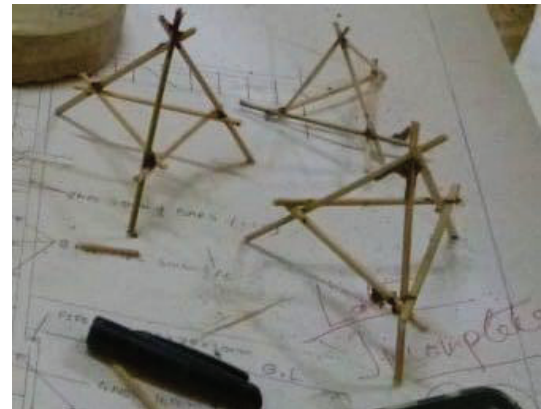


Fig 2: Prepared porcupine models

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

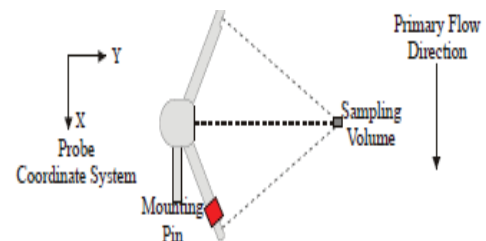


Fig 6: ADV probe orientation to stream flow

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 data 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	1.7

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

Where, L=Length of spur

IV. RESULTS AND DISCUSSIONS

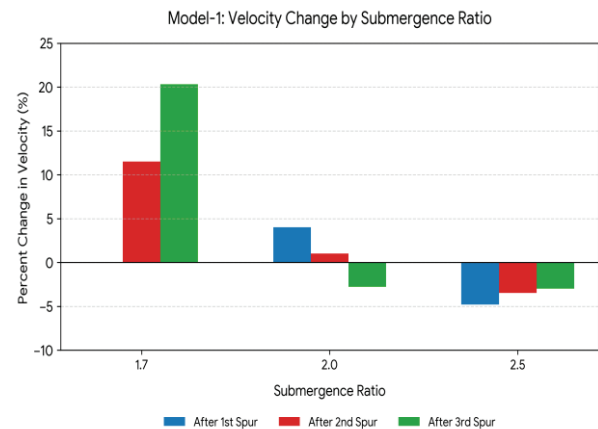


Fig 7: Change in velocity in mid channel due to installation of Model 1 against different submergence ratios

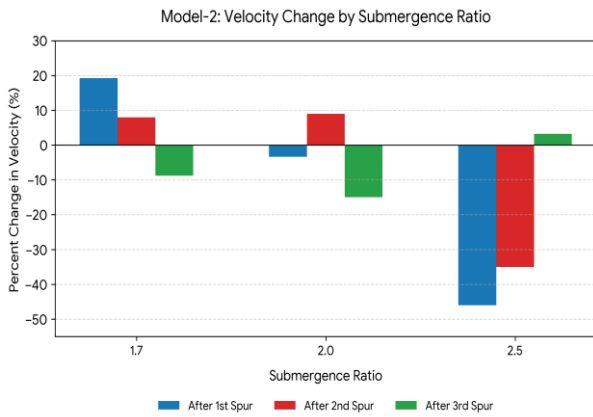


Fig 8: Change in velocity in mid channel due to installation of Model 2 against different submergence ratios

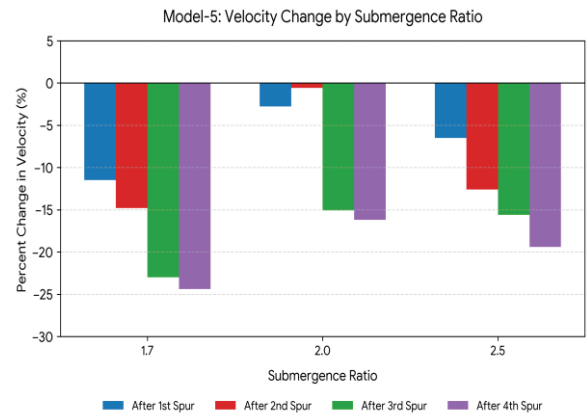


Fig 11: Change in velocity in mid channel due to installation of Model 5 against different submergence ratios

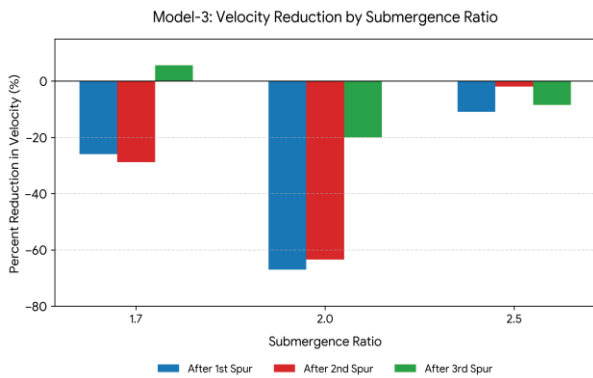


Fig 9: Change in velocity in mid channel due to installation of Model 3 against different submergence ratios

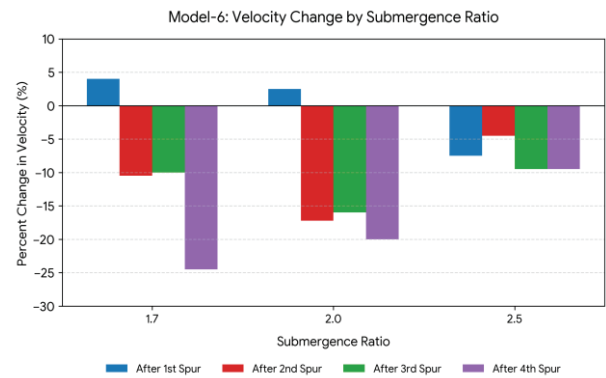


Fig 12: Change in velocity in mid channel due to installation of Model 6 against different submergence ratios

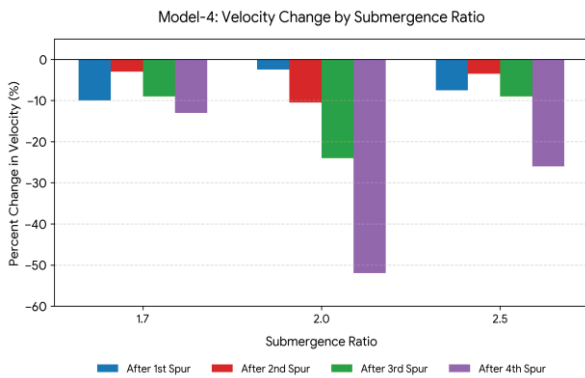


Fig 10: Change in velocity in mid channel due to installation of Model 4 against different submergence ratios

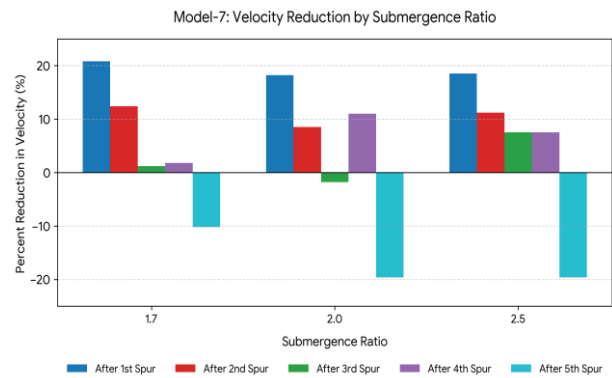


Fig 13: Change in velocity in mid channel due to installation of Model 7 against different submergence ratios

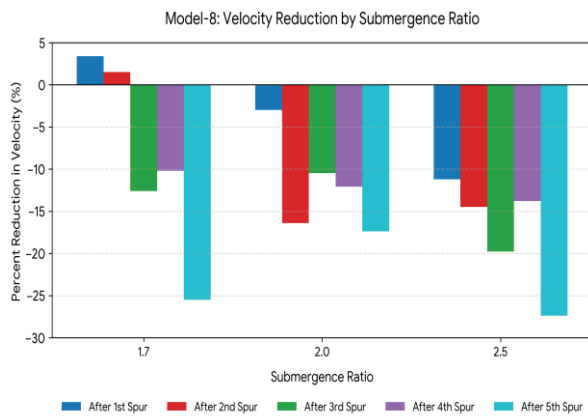


Fig 14: Change in velocity in mid channel due to installation of Model 8 against different submergence ratio.

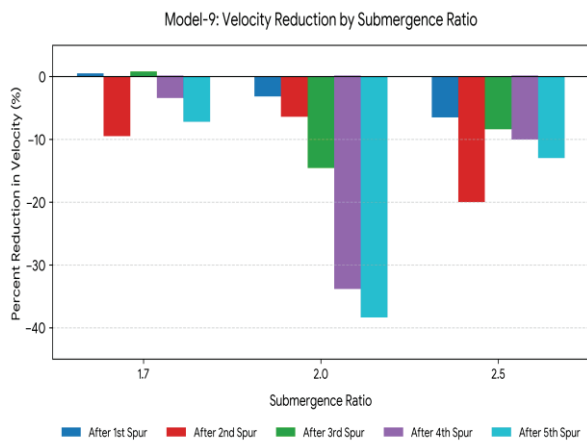


Fig 15: Change in velocity in mid channel due to installation of Model 9 against different submergence ratios

It is seen from the above figures that in cases of model 1,2,3,6,7 ,8 and 9 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 is also seen from the performances of the models from 1 to 9 that the increase in velocity in the mid channel reduces prominently as we go on increasing the number of spurs, for a particular submergence ratio. It is also observed from all of the above cases that flow diversion is not very prominent beyond the 3rd spur of the models. Hence providing more no of spurs beyond the 3rd spur does not sound very logical from flow diversion point of view.

V. CONCLUSIONS

Based on the experimental investigation, the following conclusions may be drawn:

- Flow diversion towards the mid-channel was found to increase with a decrease in submergence ratio. Lower submergence conditions enhanced the effectiveness of the permeable spur field in redirecting the flow away from the bank.
- The majority of the flow diversion occurred within the influence zone of the first three spurs. Beyond the third spur, the incremental contribution to flow diversion was observed to be relatively insignificant.
- Increasing the number of spurs beyond three did not result in any substantial improvement in flow diversion performance. Therefore, from both hydraulic and economic considerations, the provision of more than three spurs may not be justified under similar flow conditions.
- Among the configurations tested, the arrangement consisting of three spurs spaced at 3L with a submergence ratio of 1.70 exhibited the highest flow diversion efficiency and was identified as the optimum configuration for near-bank flow control.
- The study highlights that effective flow diversion depends on the combined influence of spur spacing, spur number, and submergence ratio. Within the range of conditions investigated, a spacing of 3L and a submergence ratio of 1.70 provided the most favorable hydraulic performance.

(L denotes the length of the spur).

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