# Groin Configurations: An Approach towards Stable Lowland Rivers with Improved Environmental Functions

M. Alauddin, T. Tsujimoto

***Abstract*—**Dynamicity of stream channels along with environmental concern is the key issue to address in lowland rivers like Jamuna in Bangladesh. The groins are important structures in attaining the improved river environment, but their effective functioning is not evident yet with the present design. Considering the present demands, an approach through modification of groin configurations is planned to function more natural way in dynamic lowland rivers. Four different configurations including the conventional one are considered in the study, and the changes in hydro- and morpho-dynamics affected by various structures are investigated in the laboratory. Results show that the modified combined groin favors gradual deceleration of flow towards the channel side and minimizes local scour noticeably. This favors stable regular channel and improve environmental functions.

***Keywords*—**Lowland river, dynamicity, river environment, groin configuration, local scour.

## I. Introduction

BANK recession at monsoon in sand-bed braided River, Jamuna renders millions of people homeless and landless; also insufficient flow depth for navigation at dry season disrupts the waterway transports. The river is very active geomorphologically, characterized by severe bank erosion, numerous shifting channels and so on. Though the social needs for river environment were not taken care much yet, recently these have drawn much attention to improve the ecological values of the river landscapes. The river environment which is severely affected by human activities can get relief by a series of groins through ecosystem restoration [1]. However, the performance of the existing structures in the river has been criticized by many researchers [2]-[4]. Therefore, these modern demands give rise to reconsideration of the existing groin designs and harmonization of river hydraulics and morphology.

Fully blocked impermeable groins induce strong recirculation of flow downstream of the structure [5]-[7], which may attack the bank back again where the structures installed, where the deposited land could provide ecosystem services there through vegetation and so on. Moreover, huge local scour hampers stability of such structures and loses the huge investment for them. Even destructive consequences can also be marked at downstream region after their failures. Further, sudden and big responses from these structures, in one way, leave behind strong eddies causing huge scour holes [8]-[11], responsible for the structural instability; other way, these affect other areas such as islands where numbers of people are living and make them unstable. Also, there is a presence of huge scour due to strong parallel flow at upstream side of the structure as known from the field observations [12], where the velocity is found even higher than the main channel. Some studies have also been conducted on bandal-structures for both bank protection and maintenance of navigation channels [3], [4]; however, their large-scale use at varying flow conditions is not evident yet.

The aforementioned disadvantages can be minimized with permeable groins, which decrease flow velocities near bank, hence favor sediment deposition in that area; particularly, in alluvial rivers with high sediment load. However, the conventional permeable groin, cannot guide the flow rightly to concentrate to maintain navigation depth, and some local scour can still be present near groin-tip or near bank depending on the permeability provided in the structure. To overcome these drawbacks, permeability of the structure can be varied gradually from higher to lower value so as to prevent flow separation and to achieve a gradual deceleration of flow velocities towards the bank. Thus, after gradual reduction of flow intensity, more stagnant region of flow can be developed providing impermeable portion adjacent to the bank; so that newly developed fluvial processes will allow improved environmental functionalities. The less turbulent flow climate in the groin field enhances ecological potential [13]. As the tendency of attacking the bank is minimized, deposited bed-forms of fine sediments near bank could support stable growth of vegetation, having a very important contribution to sustainable habitat. Further, the combined groin structure, if far-bank permeable portion is inclined towards downstream, could guide the flow in main channel to favor navigation depth along with minimization of strong recirculation (bank attack) and local scour (structural instability).

Thus, a modified combined groin is designed to investigate its performance including three other configurations for comparison through detailed laboratory experiments. Therefore, this paper presents the channel responses against a series of groins of various configurations to explore the nature-friendly one to promote stable river course with improved river environment.

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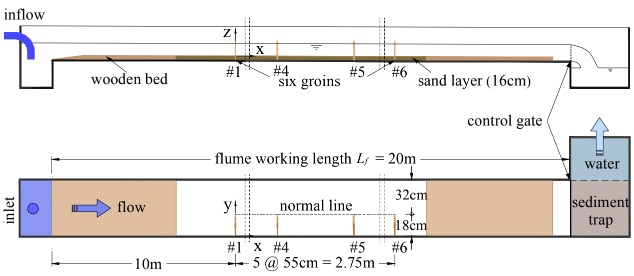
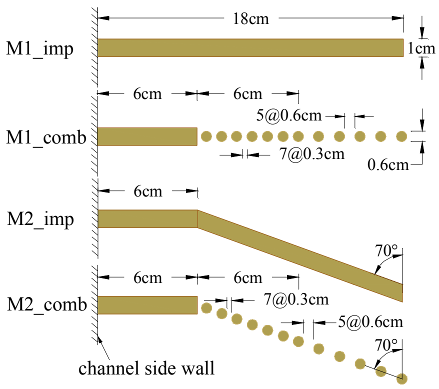
## II. Experimental Setup

The experiments are performed in a straight tilting flume of rectangular cross-section, 20.0m long, 0.5m wide, 0.3m deep. The side walls of the flume are made of a transparent weather-resistant acrylic sheet. The channel bed is covered with relatively fine and uniform sands of median size $d_{50}$ = 0.13 mm.

Four different sets of groin-models are constructed varying both alignment and permeability, where two of them are impermeable and other two are combined. First one, M1_imp, is straight impermeable; second one, M1_comb, is also straight, but first one-third portion is impermeable and rest part is made permeable. Other two models (M2_imp, M2_comb) are of same alignment, first one-third of which perpendicular to the bank and later part is aligned $20^0$ downstream, i.e., $70^0$ with the direction of flow; where M2_imp is impermeable and M2_comb is combined as in M1_comb. Permeability in combined models is varied along the length and blockage percentage is reduced from 67% near impermeable part to 50% at far-end, i.e., first-half of permeable portion is of 67% blockage and rest part is of 50%. The projected length of all groin models is $L_g$ = 18.0 cm. A set of six numbers of each model-structure is placed on one side of the channel, as the groins should preferably be installed in a series to protect a certain reach of a bank of a wide alluvial river. Figs. 1 (a)-(c) depict experimental setup, top view of groin models and channel cross-section, respectively. The model structures are installed with an interval $S_g$ = 0.55 m, i.e., aspect ratio $S_g/L_g \approx 3.0$ and cover the total distance 2.75 m by five embayments.




(a)

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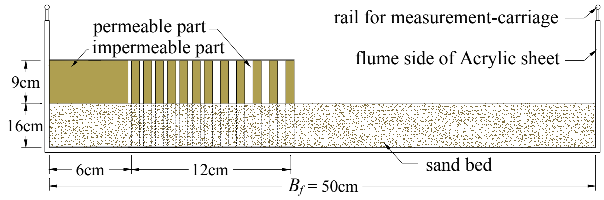


(c)

Fig. 1 Experimental Setup: (a) Side View (top) and Top View of Flume; (b) Groin Models (Planview) and (c) Flume Cross-section

An approach flow condition is maintained such that a bed shear velocity ($u_*$) be less than the critical shear velocity ($u_{*c}$) to avoid bed forms at upstream of the control reach. Two different flow discharges and approach depths are maintained for two types of groins considering similar mean velocity in the control reach from projected area of the sructures. In all tests, the groins are emerged and the Froude number ($Fr = U/\sqrt{gh}$) is small enough to ensure sub-critical flow and the Reynolds number ($Re = Uh/\nu$) is high enough to ensure fully developed turbulent flow in the control section. The details of the test runs undertaken are presented in Table I.

TABLE I
Experimental Conditions for the Entire Test Runs

| Parameters | Groin type | |
|---|---|---|
| | Impermeable | Combined |
| Flow $Q$ ($m^3$/hr) | 12.5 | 16.5 |
| Flow depth $h$ (cm) | 5.0 | 5.5 |
| Mean velocity $U$ (cm/s) | 13.9 | 16.7 |
| Sediment size $d_{50}$ (mm) | 0.13 | 0.13 |
| $u_*/u_{*c}$ | 0.88 | 0.92 |
| Froude number $Fr$ | 0.20 | 0.23 |
| Reynolds number $Re$ | 6944 | 9167 |

## III. Procedure

The flow is allowed to enter gently in the flume; when the bed is completely wetted and then drained, a profile of the bed surface is collected. The flume is then filled slowly with water and the specific flow is allowed to run. After achieving equilibrium condition, the measurements for velocity fields are made along some selected sections. To determine the performance of groin structures, three typical features are investigated critically: depth of scour near groin, deposition of sediment in the groin field and erosion in the main channel, which describe stability of the structures, anti-erosion of bank and maintenance of navigation channel, respectively. In addition to the morphological changes, hydrodynamics elucidate the environmental functionalities in the rivers.

### A. Velocity Measurements

Two-dimensional velocity components are measured utilizing an electromagnetic velocimeter, which are attached to a moveable platform. To grasp the velocity fields rightly, these measurements are taken along 9 transverse, from 2.5cm upstream of first groin to 2.5cm upstream of the subsequent groin and 16 longitudinal transects with 3.0cm intervals starting at 2.5cm from the side. The measurements are made at approximately 60% water depth to consider this as the depth-averaged velocity.

### *B. Bed Level Measurements*

After the velocity measurements, the channel is drained and after the bed is dry, typically after one day of the run, the elevation of the bed was measured in the control area using a computer aided laser sensor. Bed levels are measured in all the groin area along 18 longitudinal transects with 2.5cm intervals.

## IV. Results and Discussions

As the main two purposes of installing groins are bank protection through deposition of fine sediment near bank, hence providing important habitat for birds and maintaining thalweg for navigation, three typical features, such as scour depth near groin ($\Delta Z_g$), height of deposition of sediment in the groin field ($\Delta Z_{gf}$) and depth of erosion in the main channel ($\Delta Z_{ch}$), are considered to confirm the performance of groins (Fig. 2). Velocity distributions as well as bed topographies measured with the available setup in the selected sections are presented in this section to explore all the features as well as flow patterns influenced by the structures.

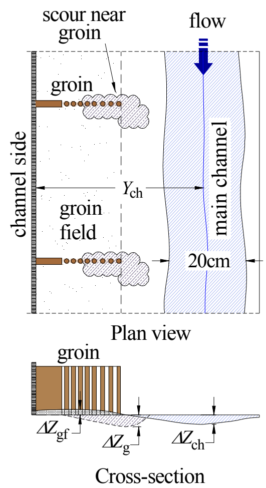


Fig. 2 Definition sketch of Key Features to Evaluate Performance of a Groin

### *A. Flow Fields*

The transverse distributions of streamwise velocities for the four models at 7.5cm downstream of first model-structure are presented in Fig. 3 to compare the flow patterns modified by different groins. This can be recognized that velocity reduces gradually towards the channel boundary the groins installed in combined groins, not sudden reduction at the end of the structure, or at the end of the impermeable part, what can be seen in impermeable structures. This modification of flow-fields can be attributed to the gradual reduction of permeability along the length of groins towards the side. Fig. 4 depicts the depth-averaged flow fields in the first groin area caused by the model structures.

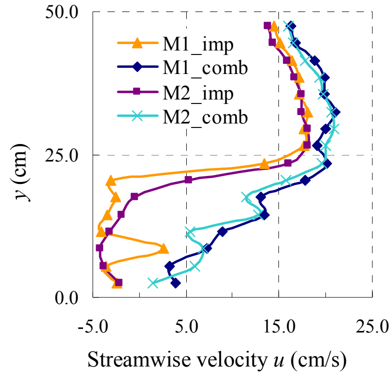


Fig. 3 Depth-averaged streamwise velocity distributions across the channel at 7.5 cm downstream of first structure

It is seen here that velocity vectors in case of combined groins (M1_com, M2_com) are significantly reduced in the groin field near bank and no strong recirculation of flow is observed as found in case of impermeable groins (M1_imp, M2_imp). These return currents, if groins are not closely spaced, are sometimes dangerous at high flood time to attack the bank and hence bank recession occurs, rather than forming sustainable riverine landscape.

### *B. Bed Levels*

The important key features to evaluate the performance of groins such as: scour near groins, deposition in the groin fields and erosion in the main channel induced by the structures can be observed from the bed topographies depicted in Fig. 5, where (relatively) higher impact near the first structure causing deeper scour as well as higher erosion in the channel bed, can be marked. Transverse profiles of bed levels (averaged over the area between second and fourth groins) for all of the structures are depicted in Fig. 6, to recognize both deposition in the groin field and erosion in the main channel induced by them.

As the flow velocity decreases significantly in the groin field, sediment settles there with different mechanisms of material transports for impermeable and combined groins. The performance of a groin in developing stable and environment-friendly river is evaluated through the hydro-morphological responses. Among the groin structures, the flow dynamics affected by the modified groin is more natural. It is free from strong recirculation of flow; the velocity is reduced gradually towards channel side. Morphological changes affected by the groins are evaluated through three key features as mentioned before. The measured maximum scour depth near the first groin, average deposition in the groin field and average erosion in the channel bed from 25cm to 45cm from the groin side, are summarized in Table II. For better understanding, these are also presented with a figure (Fig. 7). Here better responses in the channel can be recognized for the combined groin due to both alignment and permeability: local scour reduces from M1_imp to M1_comb and M2_imp to M2_comb, also from M1_imp to M2_imp and M1_comb to M2_comb.

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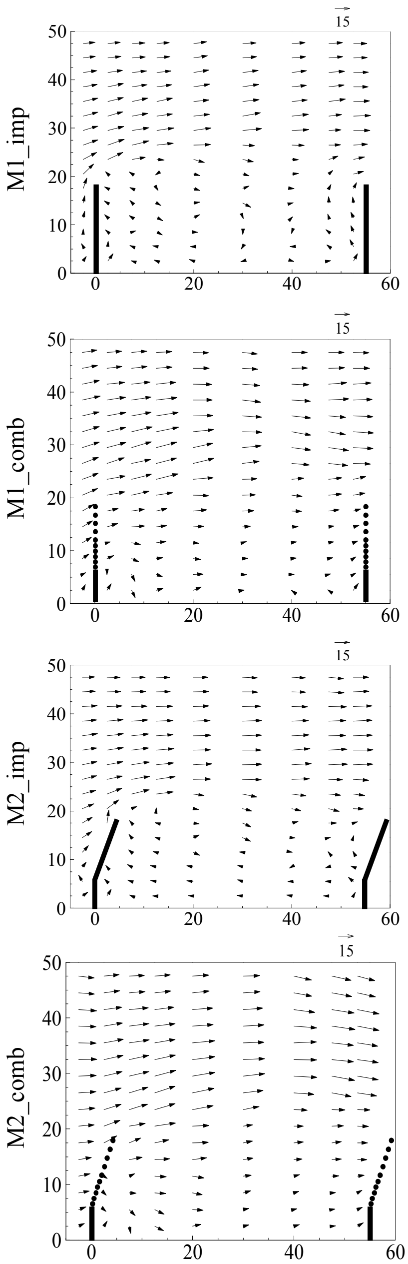


Fig. 4 Velocity fields in first groin area (distance dimensions are in cm, velocity scale is in cm/sec)

However, this trend cannot be recognized rightly for other features: deposition is found higher for M2_imp and lower for M1_imp; again erosion in the main channel is observed higher for M1_imp, then M2_imp and M2_comb; however, it was observed relatively uniform for M2_comb (Fig. 5), and it was not regular from M1_imp and M1_comb. Moreover, as seen in Fig. 5 in impermeable case, flow was reflected from the opposite side of the flume and attacked the groins in downstream area, where pronounced scour was marked (not included herein because of limited space). It could be possible by strong return currents reflecting from any hard strata on channel boundaries on opposite side; the failure of Betil and Enayetpur spurs occurred several times in Bangladesh due to such obliquely striking flow [12]. Here, the erosion in channel bed for M2_comb is found uniform and significantly improved than M1_comb due to change in its alignment.

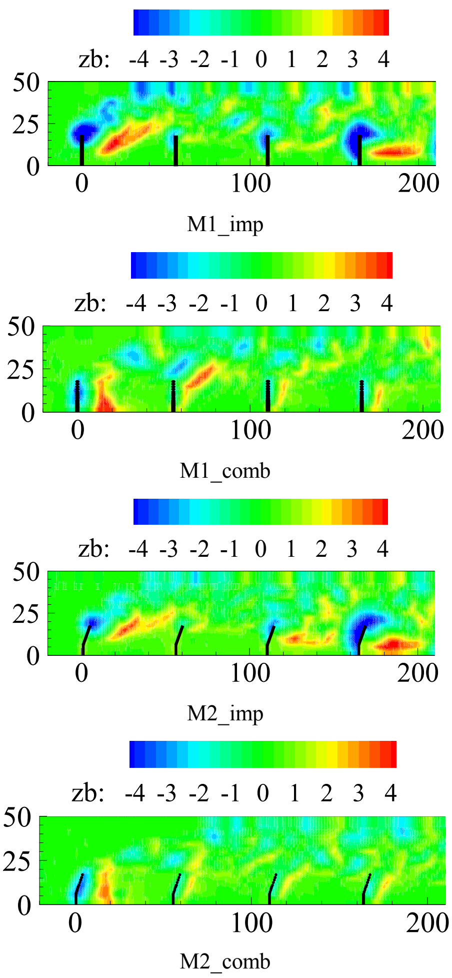


Fig. 5 Bed topographies from different model-structures

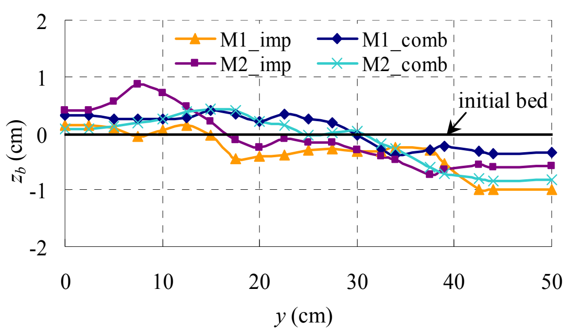


Fig. 6 Transverse bed profiles of different groin-models

TABLE II
DIMENSIONLESS FEATURES OF FOUR GROIN MODELS

| Groin model | Dimensionless features | | Groin type | |
|---|---|---|---|---|
| | | | Impermeable | Combined |
| M1 | Max. scour near groin | $\Delta Z_g/h_{imp}$ | 1.15 | 0.85 |
| | Deposition in the embayment | $\Delta Z_{gf}/h_{imp}$ | 0.01 | 0.06 |
| | Erosion in main channel | $\Delta Z_{ch}/h_{imp}$ | 0.09 | 0.03 |
| M2 | Max. scour near groin | $\Delta Z_g/h_{imp}$ | 0.91 | 0.70 |
| | Deposition in the embayment | $\Delta Z_{gf}/h_{imp}$ | 0.09 | 0.05 |
| | Erosion in main channel | $\Delta Z_{ch}/h_{imp}$ | 0.09 | 0.08 |

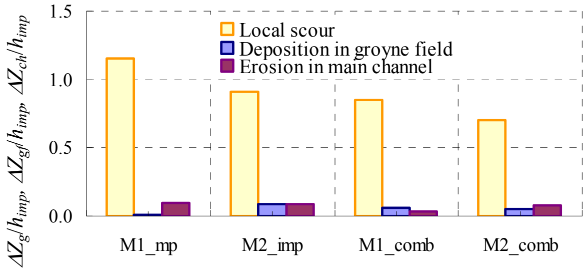


Fig. 7 Comparison of dimensionless features between groin-models: scour ($\Delta Z_g/h_{imp}$), deposition ($\Delta Z_{gf}/h_{imp}$), erosion ($\Delta Z_{ch}/h_{imp}$)

So introducing the modified design of groins, which minimizes the big diversion of flow, does not necessarily have to compromise the quality of waterway or stability of river bank, rather it provides favorable flow profiles for improved environmental functions. As bed fauna in the river system is strongly related to the hydro and morphodynamics in the main channel and groin fields, this design inclines towards a more natural one, an increase in biodiversity in bed fauna is to be expected. The spectrum of species and density of the bed fauna will become more balanced and natural.

## V. CONCLUSION

The main purpose of this study was exploring the way towards stable and nature-friendly lowland rivers through modified design of groins. From the discussion in the aforementioned section, the following conclusions can be drawn.

(i) In case of model M1_imp, high separation of flow occurs, which causes high scour near groin. Also the flow was highly diverted to hit the other wall and turned back to attack the downstream embayments.

(ii) Due to permeable nature of flow in model M1_comb, flow separation was minimized and velocity was reduced gradually, so local scour was minimized. Erosion in the main channel was not regular; rather, deposition occurred after third groin area.

(iii) The diversion of flow was moderate in case of model M2_imp, as its alignment was modified than the conventional straight one. Therefore, local scour was reduced compare to the model M1_imp, in area and magnitude both. Flow was also turned back in this case reflecting from the other side.

(iv) Modified configuration of model M2_comb in both alignment and permeability favored much lower local scour to occur than all other models; also deposition in the groin field as well as erosion in the main channel was observed relatively uniform.

As the model M2_comb offers more gradual transition of flow intensity from main channel to side, this bears a high importance for the quality of landscape. This favors stable and regular alluvial channels. The ecological connectivity increases through the permeable parts in the groins. Better migration of species can be expected in lower flow velocities.

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