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Hydraulic Performance of Some Conventional and Dagger Type Groynes

Dr S K Mazumder, *Member*
N K Gupta, *Non-member*

The object of the study reported in this paper is to analyze the various hydraulic parameters under varying flow conditions around conventional types of groynes with varying length and at given angles of inclinations both upstream and downstream, and also perpendicular to channel bank. The performance of conventional type groynes and a new shape of groyne (dagger type), adopted in Kosi river training work, have been compared. These comparisons are made on the basis of certain hydraulic parameters, namely, energy correction factor, bed-shear stress at the nose of groyne, afflux, eddy zone upstream and downstream of groyne and stream line patterns.

INTRODUCTION

Flood flow in a river is random in nature, varying widely from year to year. Average annual damage caused by floods is estimated around Rs 2000 million in India. To cope with this natural phenomenal disaster, use of groynes for river training works are popular in India. Several types of groynes have been used in most of the Indian rivers, mainly for protection of banks. Groynes are structures constructed transverse to the river flow and extended from bank into the river. Extensive studies on groynes have been carried out in the past for training and controlling rivers. A large number of experiments for deciding the various parameters of groynes, *eg*, length, shape, inclination and spacing have been carried out from time to time by various researchers. Berg and Watts[1] have suggested various types of groynes for protection of shores. Varshney[2] analyzed a number of river training measures, constructed in India, and finally proposed the design of repelling type groyne. The slotted type groyne adopted by the Central Water and Power Research Station (CWPRS)[3] is of Gabion constructions, projecting from the river bank, with gaps left in its length, which are of specific size, shape and orientation. It has been tested both in straight and curved reaches. To provide a reasonable basis for the development of principles involved in the design of groynes, Shen[4] tested various types of groyne samples. Besides these scribbled approaches, few other type of groynes such as L-head groynes, pile groynes, stone groynes, vane groynes, and sloping groynes have also been tested and utilized with success.

Though exhaustive experimental works have been done for solving localized problems as in the case of Kosi river, the problem of breaching of banks of Kosi river[5,6] still baffles engineers. Till now groynes have been provided just on the basis of experiments to solve the local problem. Very little study had been made to evaluate systematically the performance of groynes based on the hydraulic criteria. The after effects of the construction of a series of groynes were also not considered.

OBJECTIVE OF STUDY

The main objective of this study was to frame a comparative picture between conventional and dagger type groynes. However, in order to achieve this aim, the present work was undertaken on a non-mobile channel bed with an objective to:

(i) study the effect of groynes on downstream flow regime under different length, inclination and flow conditions;

(ii) determine the kinetic energy correction factor, α, indicating non-uniformity of flow, downstream of the groyne;

(iii) study the velocity distribution around the nose of the groynes near bed level in order to determine bed shear stress, τ_0, which is indicative of the scour at the nose of the groyne under mobile bed condition;

(iv) study the afflux (due to head loss) for different types of groynes under different flow conditions; and

Dr S K Mazumder is with Delhi College of Engineering, Delhi and N K Gupta was an M Sc student under the supervision of the first author.
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TABLE 1 HYDRAULIC PERFORMANCE OF CONVENTIONAL AND DAGGER TYPE GROYNES

Type of Groyne	F_e	L_e/B	ϕ	Hydraulic Performance Characteristics: α	τ_0, kg/m²	Afflux, cm	Length of eddy zone, cm: d/s	u/s
Conventional (fending)	0.6	1/4	0°	1.83	0.18	3.6	227	14
	0.3	1/4	0°	1.74	0.07	1.45	268	20
	0.6	1/3	0°	1.97	0.20	5.09	225	34
	0.3	1/3	0°	2.75	0.10	3.20	325	42
Conventional (repelling)	0.6	1/4	15° (u/s)	1.7	0.13	3.66	237	41
	0.3	1/4	15° (u/s)	2.26	0.09	2.05	297	50
	0.6	1/3	15° (u/s)	1.36	0.30	5.19	211	53
	0.3	1/3	15° (u/s)	2.58	0.05	3.09	322	63
Conventional (attracting)	0.6	1/4	15° (d/s)	2.14	0.08	3.97	230	40
	0.3	1/4	15° (d/s)	1.81	0.03	2.12	300	37
	0.6	1/3	15° (d/s)	2.11	0.17	5.04	234	47
	0.3	1/3	15° (d/s)	2.31	0.05	2.93	322	55
Dagger (repelling)	0.6	1/3	15° (u/s)	1.53	0.10	2.33	212	46
	0.3	1/3	15° (u/s)	1.49	0.04	1.06	156	38
Dagger (attracting)	0.6	1/3	15° (d/s)	1.53	0.17	2.46	205	35
	0.3	1/3	15° (d/s)	1.57	0.06	0.59	132	24

(v) study the streamline and separation patterns both upstream and downstream of groyne so as to fix up the length of eddy zone and also to examine the concentration of flow, if any.

DESIGN CRITERIA OF GROYNES

The design criteria of a groyne or a system of groynes are primarily governed by the objective for which they are required to be provided, *viz* bank protection, navigation, sediment control, etc. Main parameters in the design of groyne are : (i) length of the groyne; (ii) spacing of groyne; and (iii) angle of inclination with bank; and (iv) the shape of groyne.

In the present study, since a single groyne was tested, performance of the groyne for different lengths and angles of inclinations were found (Table 1) for different flow conditions in the channel represented by F_2, that is, Froude's number of flow at normal stage downstream of the groyne.

HYDRAULIC PERFORMANCE CRITERIA

In order to evaluate the relative performance of the dagger type groyne in relation to conventional types, following hydraulic criteria were studied :

Kinetic Energy Correction Factor (α) Measured Downstream of Groynes

α value reflects the non-uniformity of flow conditions in the tail channel. Higher is the value of α, less uniform is the flow. It is evident from Table 1 that α value for dagger type groynes are in general smaller than the conventional groynes indicating thereby the better (uniform) flow condition in tail channel. It may be mentioned that higher is the value of α, more will be the erosion in the tail channel. Thus, it may be concluded that in the case of dagger type groynes there will be less erosion in comparison to conventional ones. α values were computed by plotting isovels and by using the standard equation.

$$\alpha = \frac{\int u^3 dA}{Av^3}$$

where u is the local velocity of flow through an elementary area dA; V, the mean velocity of flow; and A, the cross-sectional area of flow.

Bed Shear (τ_0) at Head of Groyne

In the design of any groyne, the extent of scour that will locally occur near the head of the groyne must be known. Usually a factor of safety of 2.5 to 3.0 is used over Lacey's scour depth, R, given by

$$R = 1.35 \left(\frac{q^2}{f}\right)^{\frac{1}{3}}$$

where q is the intensity of flow per unit width and f, the Lacey's silt factor. Such semi-empirical formulae are, however, susceptible to wide variation in results depending on flow conditions, length, shape and angle of inclination (ϕ) of groynes. It was, therefore, decided to evaluate bed shear stress at the head of the groyne. Obviously, higher is the τ_0 value, higher will be the local scour. Table 1 shows that in dagger type groynes, scour will be far less than that in conventional ones. In all the cases, τ_0 values were found from the velocity measurement at the head of groyne by using the equation

$$\left(\frac{u}{u_*}\right) = 5.75 \log \left(\frac{30y}{K_s}\right)$$

where u is the local velocity measured at depth y above bed; u_*, the shear velocity given by $u_* = \sqrt{\tau_0/\rho}$; K_s, the equivalent sand roughness corresponding to given channel surface which was hydro-dynamically rough; and ρ, the density of water.

AFFLUX

Afflux, the change in water level upstream of groyne before and after its construction, is a measure of head loss. Greater the losses, more will be the afflux. Higher afflux results in rise of flood level upstream. Apart from rise in flood levels, there is another danger. Higher afflux will also result in greater difference in total energy level upstream and downstream of a groyne. Since there is no energy dissipator downstream of a groyne, the residual kinetic energy of flow (excess over the normal kinetic energy of flow, say, $1.10 \frac{V^2}{2g}$) will increase rendering not only in non-uniformity of flow (since the only way excess kinetic energy can be contained by a given flow is through distortion or non-uniformity leading to higher values of α), it may even cause high degree of instability of flow downstream. Such unstable flow may swing to any of the banks, causing erosion of bed and banks, meandering, etc. Table 1 demonstrates that dagger type groynes, afflux is the lowest under any given flow condition, compared to that obtained from conventional type groynes.

LENGTH OF EDDY ZONE

Transverse projections, like groynes, are bound to create long eddies upstream and downstream of such structures. Since the velocity in the eddy zone is small, sediments are deposited near the bank, thereby protecting the bank from erosion. Since the length of eddy zone is slightly lower in dagger type groynes, it will be almost as effective in the process of siltation as in the case of conventional types. Obviously, the spacing of dagger type groynes have to be little closer compared to that in conventional types, if the same amount of silting has to be obtained.

STREAM LINE PATTERN

These were plotted from the velocity distributions measured at three different sections. Comparing Figs 2 and 3, it can be stated that there is no concentration of stream lines near head in the case of dagger type groynes compared to that in the conventional types. It is due to the concentration of stream lines near the head that the conventional type groyne head undergoes tremendous amount of scour, threatening the very existence of the structure.

EXPERIMENTS CONDUCTED

Experiments were carried out in the new hydraulics laboratory of Delhi College of Engineering, Delhi. All experiments were carried out in a fixed bed masonry flume, measuring 1.5 m × 9.0 m × 0.75 m deep. Several types of models of groynes were tested in the flume. These models were made up of brick masonry. The conventional type models were oriented in three different directions—one perpendicular to the channel bank (fending groyne, Fig 1) and others 15° downstream (attracting groyne) and 15° upstream (repelling type, Fig 2), from a reference line normal to the bank. In each orientation, two different lengths of the groyne were tested : (i) one-third of the channel width $\left(\frac{L_e}{B} = \frac{1}{3}\right)$; and (ii) one-fourth of the channel width $\left(\frac{L_e}{B} = \frac{1}{4}\right)$, where L_e is the length of the groyne; and B, the channel width. Each length of groyne was tested for two different flow conditions (governed by Froude's number of flow F_2 = 0.3 and 0.6).

A special type of groyne (dagger type) was also tested under two different flow conditions, that is, F_2 = 0.3 and 0.6. Sketches showing complete details of conventional and dagger type of groynes are given in Fig 1.

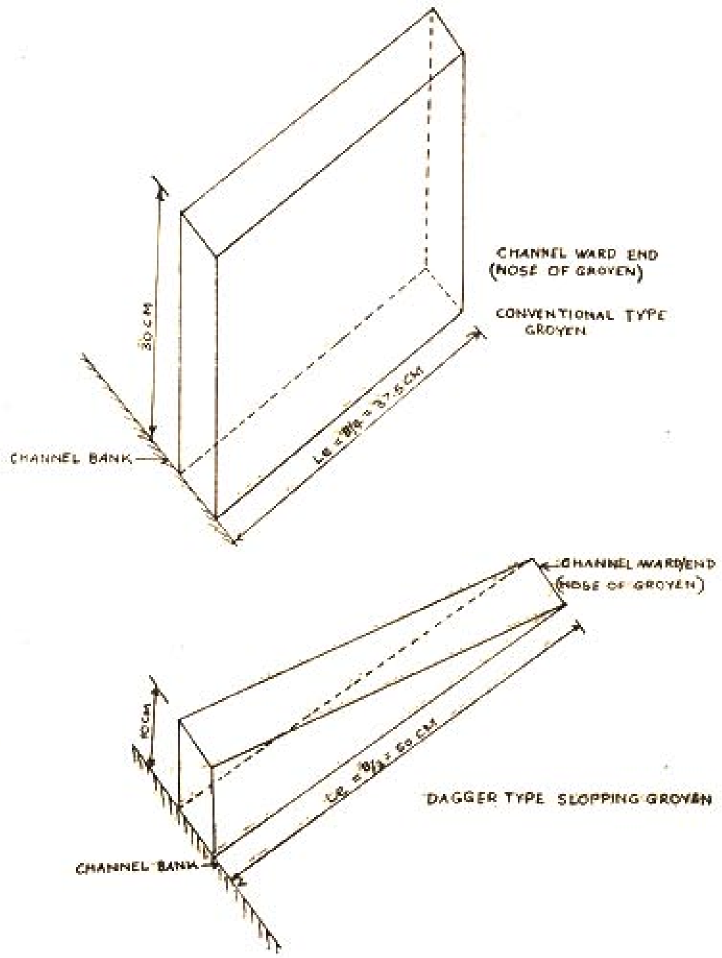

Fig 1 Conventional and dagger type groynes

RESULTS OBTAINED

For studying and comparing the behaviour of different groynes, stream line patterns for standard discharge and Froude's number of flow in all positions of groyne were plotted (Figs 2 and 3). With the help of measured velocities across the width of channel, isovels were plotted (Figs 4 and 5) and the kinetic energy correction factor, α, had been computed.

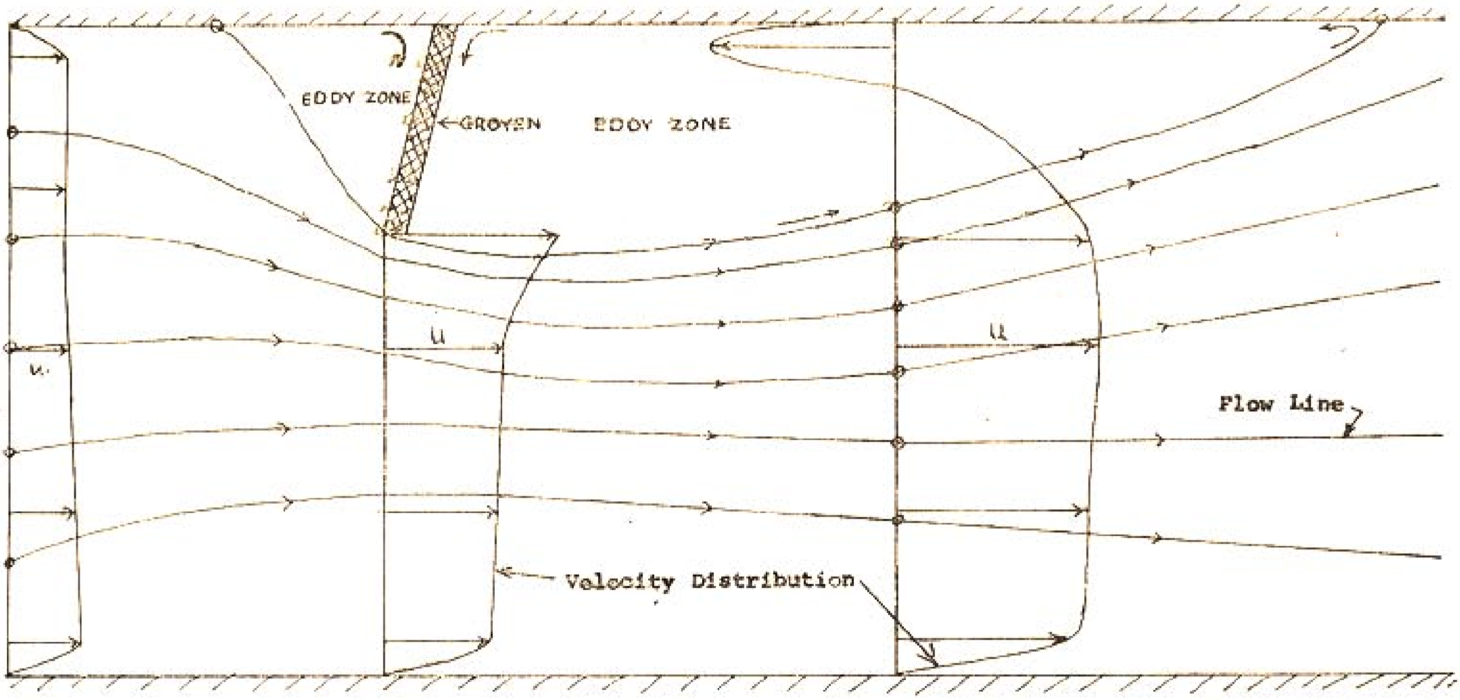

Fig 2 Flow lines with conventional type groyne inclined 15° u/s

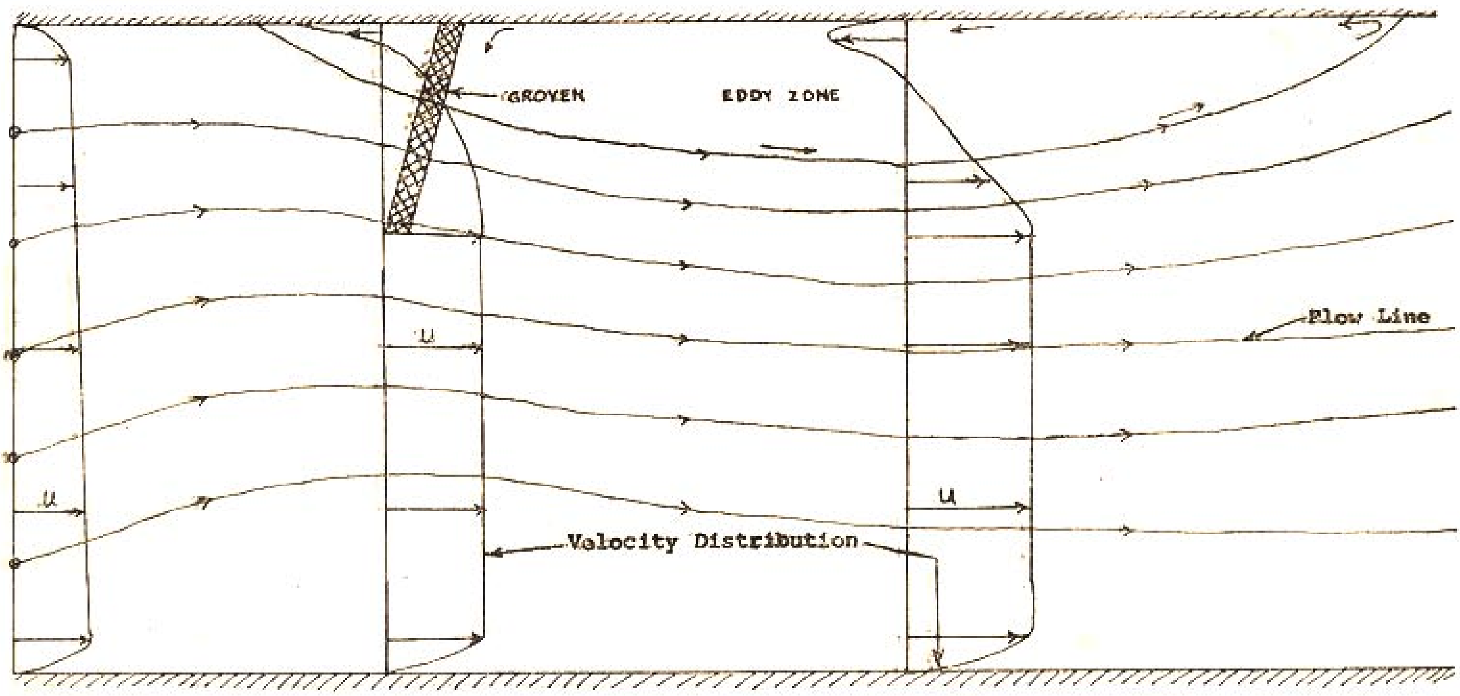

Fig 3 Flow lines with dagger type groyne inclined at 15° u/s

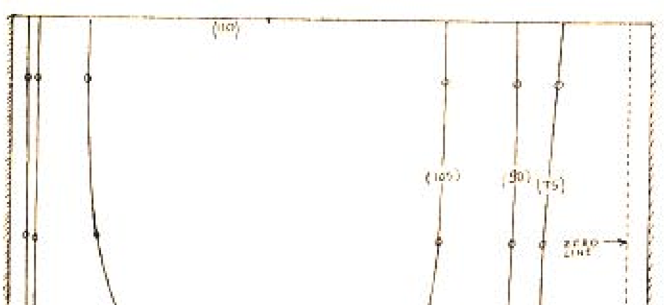

Fig 4 Velocity distribution d/s of conventional type groyne inclined 15° u/s

Besides this, observations and computations, hydraulic parameters like bed shear stress (τ_0) at the nose of groyne, afflux and extent of eddy zone have been evaluated for all lengths, orientations of the groynes and for different flow conditions ($F_2 = 0.3$ and 0.6). These hydraulic parameters are given in Table 1.

Performances of conventional type groynes have been compared with those of dagger type sloping groynes in Table 1. These comparisons can be made on the basis of hydraulic parameters as already discussed.

CONCLUSIONS

1. It is found that all hydraulic parameters like kinetic energy correction factor, α, afflux, bed shear stress, τ_0, at the nose of groyne and extent of eddy zone, increase with increase in length of groyne.

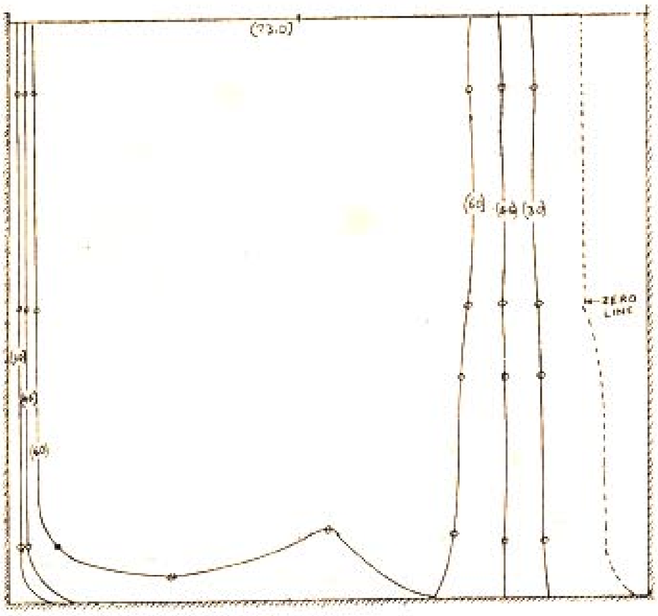

Fig 5 Velocity distribution d/s of dagger type groyne inclined 15° u/s

2. Maximum value of α is found to be 2.75 for conventional type groyne placed normal to bank ($\phi = 90°$) for $\frac{L_e}{B} = \frac{1}{3}$ and $F_2 = 0.3$.

3. The bed shear stress at the nose of the groyne, afflux and the length of eddy zone downstream of groyne increase with increase in Froude's number of flow. However, the α value decreases with increase in Froude's number in most cases.

4. Considering the performance of conventional groynes, inclined 15° upstream and those inclined 15° downstream, it may be observed that the performance of groyne inclined downstream is better than that inclined upstream from the point of view of scour at the head of groyne.

5. Comparing the various hydraulic performance of dagger type inclined groynes with those of conventional type groynes as stated earlier, it may be concluded that dagger type sloping groynes are superior to conventional groynes in all respect, except that it is not as much effective to induce silting as in the case of conventional type groynes. It can, however, divert the flow to protect the bank effectively. Hydraulically, a dagger type groyne inclined upstream (repelling type) is superior and should be always placed as such.

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About the Authors

Dr S K Mazumder

Dr Mazumder obtained B E degree in civil engineering from Calcutta University, and M E degree and Ph D from IIT, Kharagpur. He has three years experience in field work and 24 years in teaching. He has published 40 papers and has guided several students for post-graduate degrees and Ph D. During 1983-86, he was Head of Civil Engineering Department and Dean, Faculty of Technology, University of Delhi, Delhi.

Shri N K Gupta

Shri Gupta has passed his B E degree from College of Engineering, Pantnagar University and completed M E degree in civil engineering from Delhi University in 1984. At present, he is with Delhi Development Authority as Assistant Engineer.