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EFFECTIVENESS OF IMPERMEABLE TYPE GROINS IN RIVER TRAINING WITH PARTICULAR REFERENCE TO RIVER KOSI IN INDIA

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SUMMARY

Prior to the construction of Kosi barrage and the flood embankments, the river Kosi is known to have shifted its course over a width of 112 km, incurring loss to both life and properties. Even after the construction of the barrage and the embankments, the river continued to attack the banks causing several breaches. A total number of 284 impervious type groins have been constructed at an enormous cost to protect the embankments. One of the primary objectives of writing the paper is to discuss the effectiveness of the groins in training the river Kosi.

Flow downstream of the barrage is unstable due to incomplete dissipation of energy in the drowned jump. Even with 2% residual kinetic energy, the flow distribution is so non-uniform that the kinetic energy correction factor (α) attains a value of nearly 4. Theoretical and experimental values of α have been plotted against jump efficiency.

Groins projecting inside the river causes sudden contraction and expansion of flow resulting in head loss and afflux. Flow downstream of an impermeable groin is unstable due to presence of residual kinetic energy of flow. Values of α , afflux, shear stress (at head of the groin) etc. for different types of groins as obtained in a model study have been presented.

It is concluded that the flow which was already unstable downstream of Kosi barrage has been rendered further unstable due to construction of a large number of impermeable groins, some of which project deep inside the river. Attack of the river Kosi on its banks and groin systems will continue to occur till the flow remains unstable. The natural question is, therefore, whether the groins are at all effective in training the river Kosi.

NOMENCLATURE

F_1	=	Prejump Froude's number of flow.
η_j	=	Efficiency of jump as energy dissipator.
ΔE	=	Difference in normal total energy levels upstream and downstream of the barrage i.e. the amount of energy required to be dissipated.
$\Delta E'$	=	Amount of energy actually dissipated in the reach of stilling basin.
α	=	Kinetic energy correction factor.
u	=	Local velocity of flow through an elementary area (dA)
A	=	Area of cross-section of flow.
V	=	Mean velocity of flow.
L	=	Length of groin.
B	=	Width of channel.

1. INTRODUCTION

Groins have been used extensively in the past for the protection of banks of river and sea-shore. In river training for navigation, groins help maintaining a deep channel. Projected from the banks into the river side, impermeable type groins obstruct the current causing slack flow in the region in between the groins. The mainstream is deflected away from the bank provided with groins. Thus the bank is safe against erosion from high velocity stream which moves away from it. If the river water contains sediments, the region in between the groin is gradually silted up due to slack motion. In this process, new bank is built up and the main river is gradually shifted to the other side of the bank previously under attack.

2. BRIEF HISTORY OF KOSI RIVER TRAINING WORKS

River Kosi originating from the Himalayas travels 468 km through Tibet, Nepal & Bihar in India and joins ultimately the river Ganges near Khursela in Bihar. Earlier to the construction of flood embankments, the Kosi river is known to have changed its course across a width of 112 km - sometimes in the east and sometimes in the west - with its apex at Chatra (in Nepal) where it comes down from the hills to the Plain. It had brought immense miseries by way of loss of life and property in the State of Bihar in India and in Nepal. In the year 1946, there was a proposal to construct a high dam (239m) at Barakshetra (in Nepal) with a storage capacity of 8500 M.Cu.m. at a tremendous cost involved (estimated cost of Rs.1750 Million in 1946). Finally a barrage was constructed at Hanumannagar (in Nepal) in the year 1963. Two numbers of embankments - one on the east (144 km long) and the other on west (123 km long) were constructed from Hanumannagar barrage to Khursela (out - fall point). Fig. 1 illustrates the plan and sectional view of the barrage. Primary objective of the embankments was to channelise the river and prevent its free oscillations. Planners of the project - concerned more with cost optimization - did not, perhaps, appreciate at that stage the various problems faced subsequently. M/s.Torpen & Raw Housen, Consultants (ref.1) had said, "It seems probable that maintenance of Kosi embankments will be a major operation, especially in the reaches where heavy silt deposition occurs and channel deviation may produce direct attack on the embankment at some places." The prediction have been proved to be correct. Downstream of the barrage, the river was unstable (explained in the following paragraph) and it started attacking one embankment or the other. In the year 1968, four numbers of breaches occurred in the western embankment. Similar damages had occurred in the eastern embankment also. Authorities became concerned due to the continuous attack of river Kosi on either of its embankments. As many as 284 Nos. of impermeable groins were constructed. -52 on the western embankment and 232 on the eastern embankment. Fig. 2 illustrates the groin system built on western embankment alone. In spite of these elaborate and costly protective measures, there was again a breach of 1500m width in the eastern embankment in the year 1984, resulting in wiping out of 43 villages. Over One hundred thousand people were rendered homeless and 40,000 hectares of fertile agricultural land had turned barren due to deposition of sands. Actual loss of life is not yet known.

Primary objective of writing this paper is to examine how far these groins have been effective in training the river Kosi so as to channelise the river in a defined course.

3. INSTABILITY OF FLOW IN THE RIVER DOWNSTREAM OF KOSI BARRAGE

When a barrage is constructed across a river, the normal width of flood plain is constricted laterally for economy. For example, the length of the Kosi barrage at Hanumannagar is 1150m, whereas the width of flood plain in between the embankments at Hanumannagar is 6,900m (Fig.1). Due to construction of a concrete floor protected by sheet piles, the river section is restricted further as it cannot scour its bed and banks freely. Moreover, the height of the crest (solid obstruction) is 1.5m above the upstream river bed as shown in Fig 1. Such constrictions, both laterally and in the vertical plane, cause afflux during the passage of flood flow. Allux in Kosi barrage corresponding to the design flood of 27,000 cumecs is 3.6m. Prejump Froude's number (F_1) at the toe of spillway is found to be 3.10.

It is well established that the hydraulic jump is oscillating and unstable when F_1 lies between 2.5 and 4.5. Efficiency of the jump (as energy dissipator) is less than 100% when $F_1 = 3.10$. Here the jump efficiency (η_j) is defined as

$$\eta_j = \Delta E' / \Delta E$$

Where ΔE is the difference in R.L. of the normal total energy lines upstream and downstream of the barrage i.e. the amount of energy required to be dissipated and $\Delta E'$ is the amount of energy actually dissipated in the reach of the stilling basin. The difference between ΔE and $\Delta E'$ is termed as leaving Kinetic energy (or residual Kinetic energy) of flow (fig.3). Even a small amount of residual Kinetic energy causes distortion of flow and non-uniform distribution of velocity, resulting in high value of energy correction factor, α , given by

$$\alpha = \int u^3 dA / AV^3$$

Where u is the local velocity, A is the area of flow section & V is the mean velocity of flow. Referring to Fig.3, flow in between sections 1-1 & 2-2 is non-uniform due to incomplete dissipation of energy. At section 1-1, α - Value is very high. As the residual K.E. of flow is gradually dissipated through eddies in the reach 1-1 to 2-2, the flow becomes more and more uniform; α -value gradually decreases and is almost normal at section 2-2 far downstream of the barrage. Fig.4 gives the relation between α and the jump efficiency (η_j) as obtained both theoretically & experimentally in a model study (Ref.2). It may be seen that even 2% residual K.E. of flow (equivalent to 98% jump efficiency) is sufficient to cause enough distortion of flow resulting in $\alpha \approx 4.0$. Higher is the residual K.E. of flow, greater is the non-uniformity of velocity distribution and higher is the value of α . Partly due to inefficient jump (at $F_1 = 3.10$) and partly due to sudden expansion (from 1150m to 6900m), flow downstream of Kosi barrage is expected to be highly non-uniform. Live flow, under such situation, becomes unstable and often starts wandering from one bank to the other (Ref.3).

4. INSTABILITY OF FLOW DOWNSTREAM OF AN IMPERMEABLE GROIN.

An impermeable groin, as shown in Fig.5, causes lateral constriction on one side - the extent of constriction being dependent on the length of the groin. A groin projecting inside a river causes sudden contraction of flow upstream and sudden expansion downstream. The head losses due to contraction and expansion of flow give rise to afflux and thereby change in energy level upstream and downstream of the groin. Unlike barrage, there is no stilling basin downstream of a groin for bringing about dissipation of energy. The flow just behind the groin contains large amount of residual Kinetic energy, leading to formation of eddies and non-uniform distribution of velocity resulting in high values of α . A long groin projecting deep inside the river may cause great instability of flow which may start wandering downstream. Hydraulic performance of impermeable groin e.g., afflux, bed-shear stress and kinetic energy correction factor (α), (found in a model study (ref.4) in the hydraulics laboratory of Delhi College of Engineering, Delhi) are given in table-1. Big eddies were found to occur downstream of the groins (fig.5) resulting in non-uniformity of velocity distribution and instability of flow.

5. CONCLUSION

It may be concluded from above that the flow which was already unstable downstream of the Kosi barrage has been rendered further unstable due to construction of a large number of long impermeable groins some of which project deep inside the river. No amount of groins can make the Kosi embankments safe unless the basic cause of instability is removed and the flow is rendered stable. It is to be kept in mind that when the river flow becomes unstable, the direction of flow is unpredictable. Meandering of flow, erosion of bed and banks, outflanking of groins are all basically due to instability of flow. The flow may attack one bank or the other creating deep channels near the embankments and thereby threatening the very existence of the embankments. All the above phenomena are reported to have occurred in Kosi river after the

construction of the barrage, the embankments and the groins built to protect the embankments.

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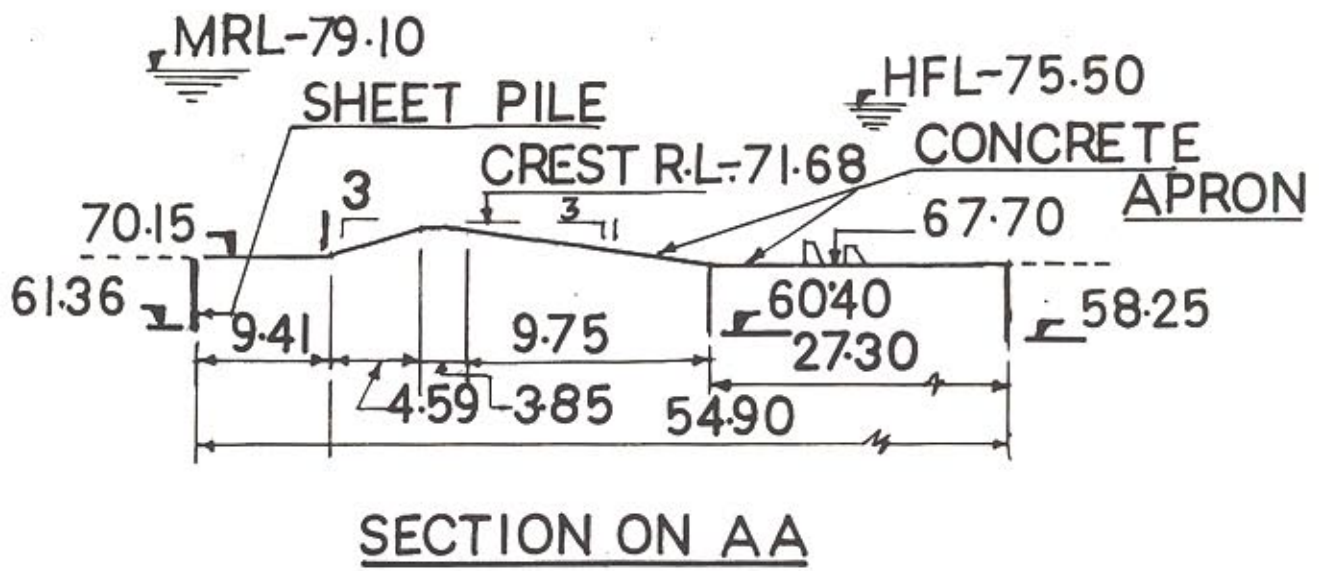


FIG. I-A SHOWING SECTION OF KOSI BARRAGE

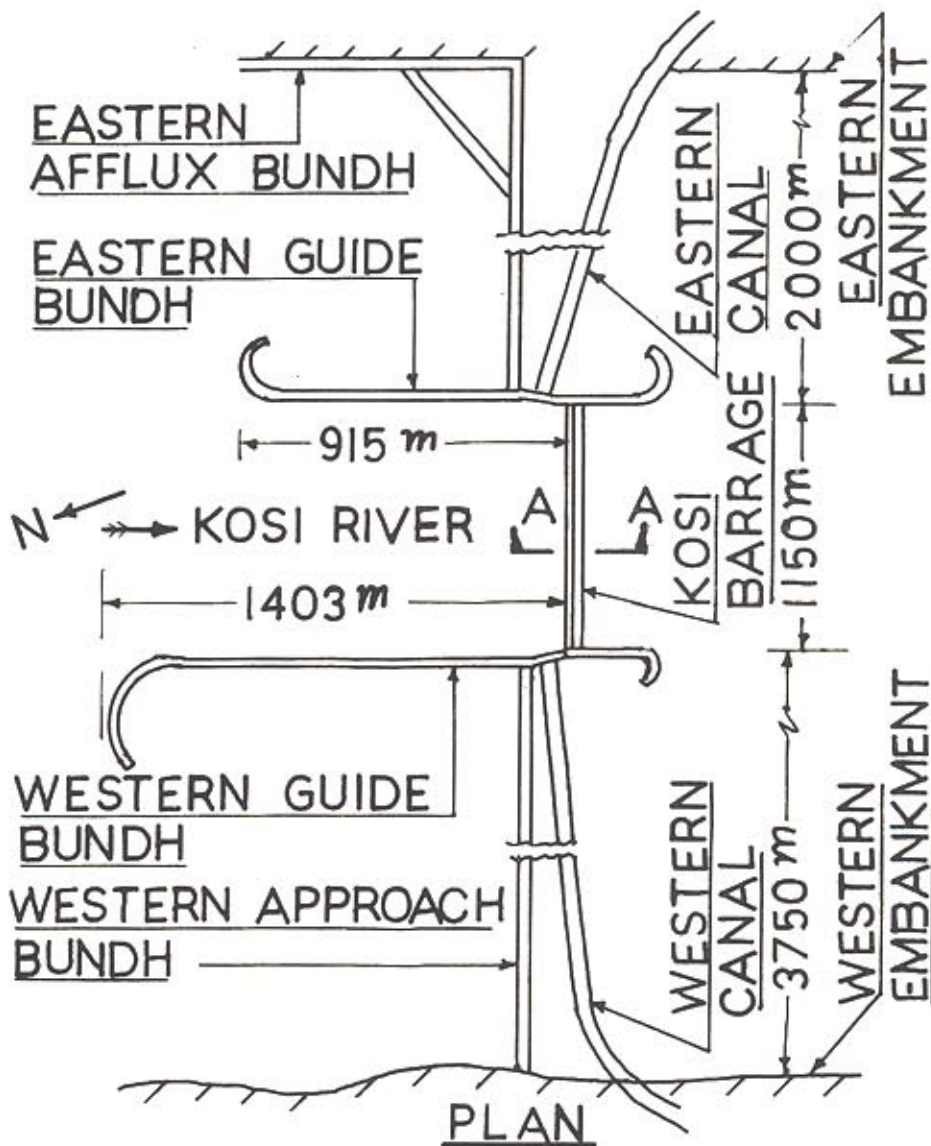


FIG. I-B SHOWING PLAN OF KOSI RIVER

SCALE : 1CM = 400M

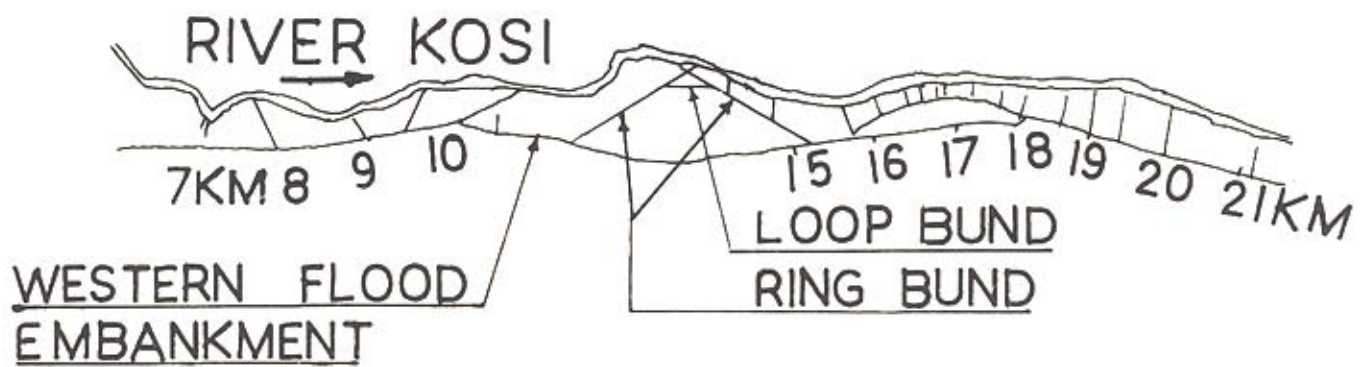


FIG.2 GROIN SYSTEM ON THE KOSI EMBANKMENT

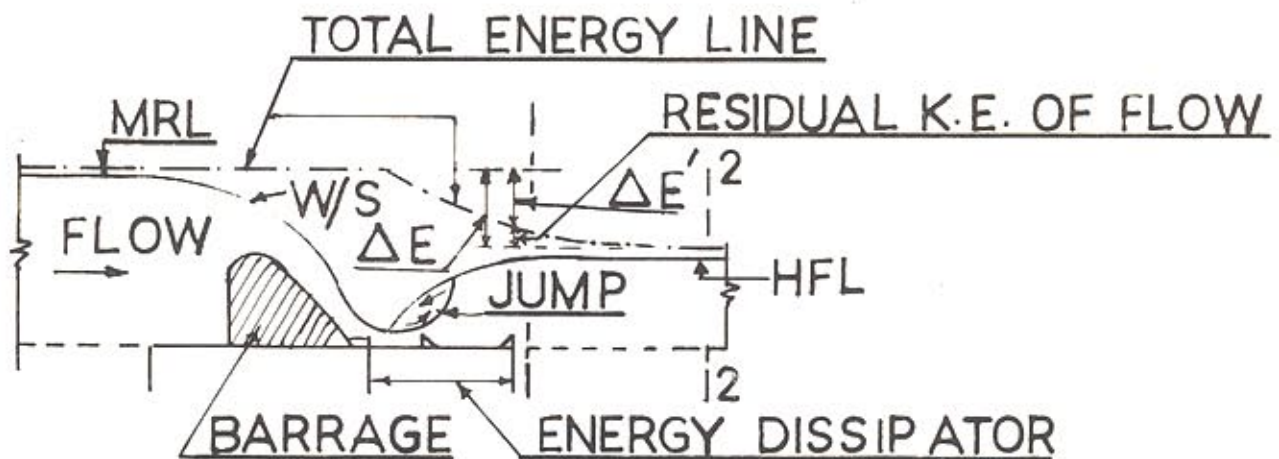


FIG.3 SHOWING RESIDUAL K.E. OF FLOW

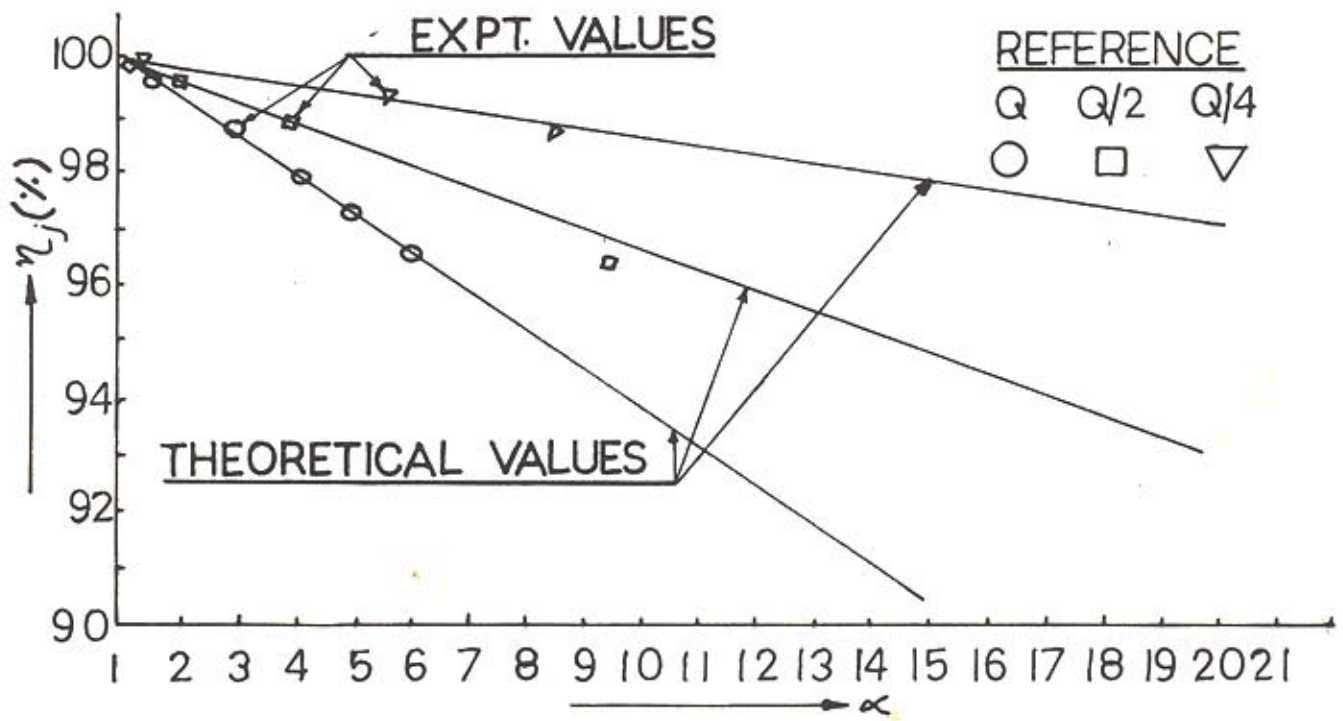


FIG..4 VARIATION OF EFFICIENCY(η_j) WITH ENERGY CORRECTION FACTOR (α)

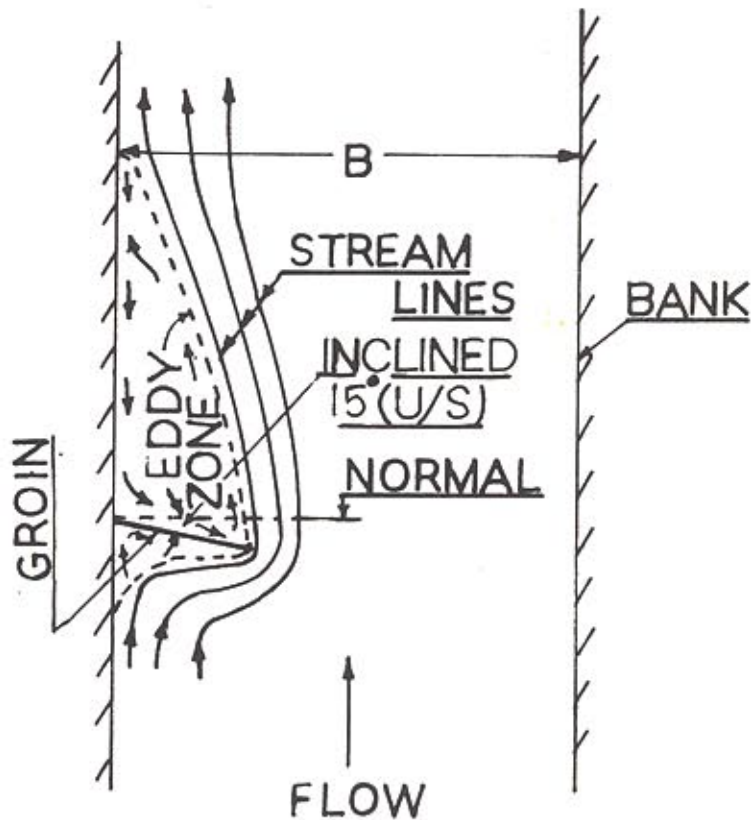


FIG.5 SHOWING FLOW PATTERN WITH A GROIN