MORPHOLOGY AND TRAINING OF RIVERS NEAR BRIDGES

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Abstract

All civilizations in the past have developed in areas around water bodies like rivers which occupy a prominent place at every stage of all human development. Rivers flowing in their natural state behave in different forms depending on slope, discharge of water and transport of sediments and may cause serious problems to the people living in the vicinity of rivers. River training is necessary for making better control and greater use of river and river water. An untrained and uncontrolled river may bring devastation due to flooding, change in course, braiding, meandering, scouring of bed and banks, breaching of embankments, damages of hydraulic structures like bridges, embankments, roads and railways etc. In this paper, author has made an attempt to summarize the river behavior in its different stages and the problems encountered. Different types of river training measures and their selection have been narrated.

1. INTRODUCTION

Water flowing through rivers is one of the most important natural resources for survival of mankind and other living beings. Historically, all civilizations in the past have developed in areas around water bodies like rivers which occupy a prominent place at every stage of all human development. Some of the most important usage of river and river water are:

a) Municipal and domestic use

b) Agricultural and Industrial use

c) Power generation – Hydro, thermal, nuclear etc.

d) Drainage – Storm water run off, municipal wastes etc.

e) Life support for fish, animal, forests other flora and fauna

f) Transportation, recreation, health resorts etc.

g) Recharging ground water at high stage and maintaining dry weather flow at low stage .

Except some rivers in the Himalayan region, most of the rivers in India are rain fed. Unlike Europe, snow fed rivers are only a few flowing from high altitude in the Himalayas e.g. Ganga, Brahmaputra, Satluj etc where 10-15% of runoff are from snowmelt. Run off distribution in most of the rivers are, therefore, directly related to distribution of rain fall. High intensity of rainfall for a prolonged period causes flooding and drought occurs due to scanty and insufficient rainfall. Both flooding and droughts bring about damages to crops and other properties besides loss of life, disruption in communications etc. Losses are more as the people encroach on flood plains for proximity of water body, fertility of land, cheap land etc. When the river is in high stage, people leave their properties and undergo sufferings which cannot be measured in terms of money.

Both the central and state governments have to spend huge sum of money for relief and rehabilitation of people affected by floods and droughts almost every year. Flood embankments are constructed for providing security of life and properties. Costly maintenance of roads, railways, hydraulic structures such as bridges, barrages, intake works, river training works etc. are to be carried out regularly. One of the most common causes of flooding is breaching of flood embankments. Repair of breaches and protection of flood embankments are very costly affair. Training of a river near bridges and barrages by construction/repair of spurs, guide bunds, mattressing of approach embankments, construction of marginal /afflux embankments is extremely costly .Without proper training, rivers scour foundation and tend to outflank the structures, due to backwater effect resulting in aggradations, degradation, river widening, meandering etc.

All rivers originate in high altitudes and flow downwards with outfall in sea with almost zero elevation (or in a lake or in another major river). The valley setting of rivers can be broadly subdivided into:

a) Mountainous or hilly region with very steep slope (1 in 10 to 1 in 100 aproximately)

b) Sub-hilly or trough stage where slope reduces considerably (about 1 in 100 to 1 in 1000)

c) Flood plains with mild slope (about 1 in 1000 to 1in 10000)

d) Delta stage near its outfall into the sea (less than 1 in 10000 approximately)

Types of river training to be adopted are dependent on its valley setting. In the mountainous stage, the river has so high stream power (product of discharge 'Q' and bed slope 'S_0' i.e. QS_0 gives stream power per unit width of stream and unit weight of water). that the flow carries boulders and gravels along the bed. In this stage, river flows in a narrow gorge and a number of small and medium streams join on the way. They are highly degrading (due to very high velocity) and carry sediments brought down from their catchments through formation of reels / nullies / gullies etc and also due to land slides. Training measures in this stage, therefore, should be aimed at control of erosion /hill slides through check dams, soil conservation in catchment areas, prevention of toe erosion etc. (by short stone spurs or by gabion walls etc).

In the sub-hilly or trough stage, stream power is considerably reduced (due to reduction in bed slope, S_0) resulting in deposition of boulders and gravels. In this aggrading stage, the channel, through which streams flow, gets filled up with sediments and the stream starts flowing in a new channel. In this process, multiple channels are formed and the river goes on shifting its course resulting in delta like formation. Training a river in such an unstable braided stage is extremely difficult and the river often outflanks the hydraulic structures like bridges, barrages, training works such as spurs, Guide bunds etc. Often it breaches embankments, roads, railways etc. Dredging of sediments and lining of channels etc to improve conveyance of the river is a better proposition. As the river descends into flood plains, the bed slope and stream power reduces further and even the finer fraction of sediments i.e. fine sand, silt etc get deposited on alternate banks resulting in meandering flow and formation of wide flood plain (also known as khadir or meandering belt) as shown in Fig.1.

Because of the settlement of people in the fertile flood plain of a meandering river, flood embankments (also called levees, dykes, marginal bunds, flood embankments etc) are popular measures of river training for protection of people and their properties near river banks. Although constructed sufficiently away from river banks, these embankments are often subjected to river attack due to migration of meanders both laterally and longitudinally. In all such vulnerable reaches, embankments are to be protected with revetment/ pitching / mattressing etc. to arrest erosion of bed and bank and prevent breaching of embankments. Long / short spurs (both permeable and impermeable) are constructed to dampen / deflect the high velocity flow against direct attack by the meandering river. When hydraulic structures e.g. such as bridges / weirs / barrages are constructed

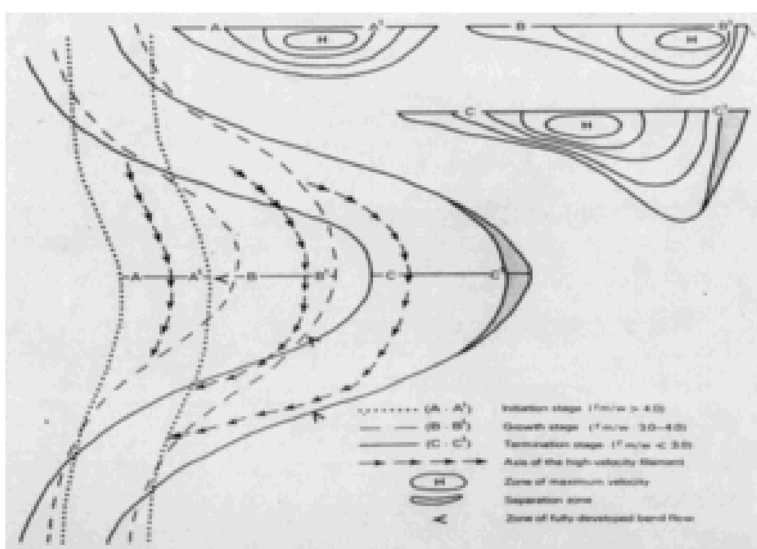


Fig. 1 Lateral Migration of Meander and Stream cross Sections in a bend

in a wide khadir, its water way is often restricted with approach embankments (Fig.2) in order to reduce cost. Flow field which used to prevail before construction of such structures get altered after the construction of the structures. Regime of river is changed and new pattern of meanders develop both upstream and down stream of such structures. The river is in aggrading stage due to deposition of sediments upstream (due to afflux and back water), causing substantial loss of stream power. Degradation occurs immediately down stream of the structures due to high velocity and residual kinetic energy of flow, higher turbulence and comparatively clear water flow downstream.

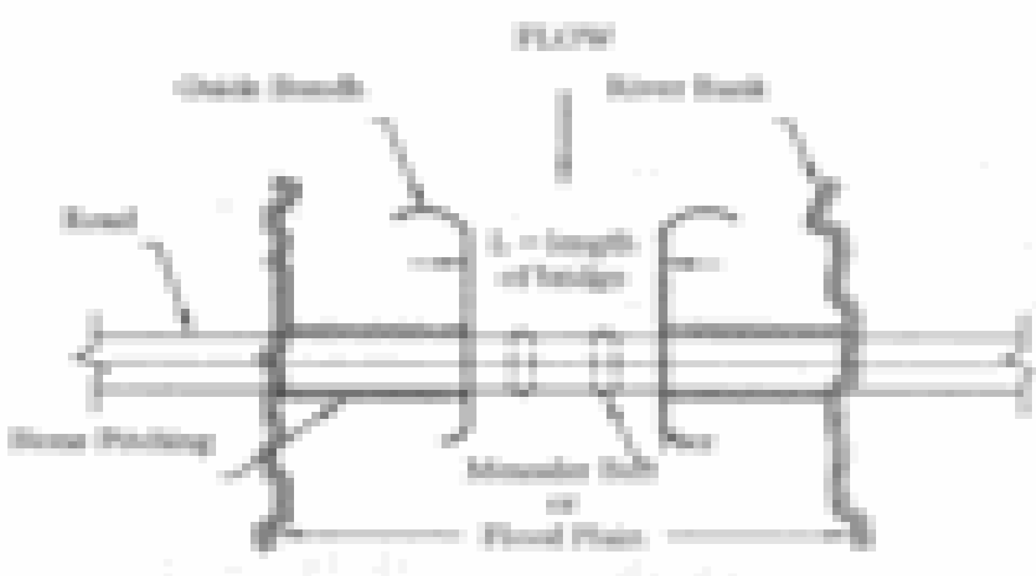


Fig. 2 Restriction of Waterway under a bridge by Use of Guide Bunds

One of the major evil effects of embankments and jacketing of a river is due to the fact that the country side looses the fine and fertile sediments which are deposited within the embankments thereby raising river bed level and lowering country level causing drainage congestion in the country side. In case of sudden breaches, there is wide spread and unprecedented flood damage (Fig.3a,b). Sometimes river changes its course rendering all hydraulic structures down stream useless and requiring new structures.

As already mentioned, meanders move both laterally (at faster rate) and longitudinally (at slower rate) causing formation of wide flood plain (khadir) with shallow flow depth during lean season. Spurs are helpful in narrowing khadir width and increasing flow depth for navigability of river. Strong flow curvature in wildly meandering river can be controlled by cut-off which helps in straightening of the river and improving its navigability. In _the final stage of its journey (before joining sea), the bed slope reduces to such an extent (1 in 10000 to 1 in 20000), that even the fine silts and clays transported by the river (as suspended load) get deposited forming deltaic islands e.g.Sunderban and Mahanadi deltas. Because of large volume of flood water and siltations, river starts flowing in multiple channels. Distribution of flow in these channels alters periodically resulting in spill flow and damages to crops and habitats. Some of the rivers are also subjected to tidal effect. During high tides, rivers carry

Fig.3(a) Disastrous Flood in Malda District in West Bengal after Breach of Left Marginal Embankment Upstream of Farakka Barrage, in the year 1998

Fig. 3(b) Devastation brought about by river Kosi due to change of its course on August 18 th, 2008 due to Breach in its left Embankment about 12 km upstream of Kosi Barrage

sea water and transport silt upstream. Training of rivers in the deltaic reaches consisting primarily of levees is a very difficult task. If it is a navigable river, maintaining minimum depth of flow for navigation is one of the objectives of river training in these reaches where the river widens and silts up.

2.0 RIVER MORPHOLOGY

Proper understanding of river behavior in the vicinity of bridges is extremely important for planning, design and layout of river training works for their safety. Flow field, which used to prevail prior to their construction is changed. There is afflux subjecting the channel to backwater effect upstream. Hydraulic and energy gradients are decreased resulting in loss of stream power and deposition of sediments upstream of the structure. On the downstream side, there is generally degradation near the sructures due to low sediment content, residual kinetic energy of flow and higher turbulence level. Uncontrolled aggradations/degradation causes a lot of problem. The river tries to widen and outflank the bridges. Costly protection measures are to be adopted to make the river flow axially through the brides. Depending upon the amount of restriction, the approaching flow may often become unsymmetrical and unstable. Such river may shift their location and may wander anywhere within the wide flood plain (khadir) resulting in erosion of both bed and banks of the river. It may also breach/ washout the protection works

2.1 Aggradations/ Degradation

Understanding of river behavior is complicated due to integrated geo-morphologic, hydrologic, hydraulic and sediment parameters. Inter relation between river plan form, hydrologic, hydraulic and sediment parameters and relative stability of the river is illustrated in Fig.4. It may be observed that the different plan forms i.e. straight, meandering, braided etc. depend on the river geometry, sediment load, slope and flow in the river.

Quantitative prediction of river response due to climatological and watershed change is based on the fundamental relation given by Lane(1957).

$$QS_e \;\alpha\; Q_S\, d_{50}$$

Where Q is the flow rate, S_e is the energy gradient, Q_s is sediment transport rate and d_{50} is the mean size of sediments being transported. Fig 5 illustrates the regime diagram given by Lane for quantitative prediction of river regime.

2.2 Change in River Regime due to Human Interference

Aggradations / degradation near bridges/hydraulic structures is mainly due to the loss in balance between sediment supply and transport rates. Rivers attain a stable regime over hundreds of years through adjustments of its slope and section according to volume of water and sediments carried by it. Many gifted river engineers like Lacey(1930), Blench (1957), Lane (1957), Diplus (1990) et al from abroad and Garde(2006), Rangaraju (1970), Chitale(1970)et al from India have done considerable work to predict the regime state and corresponding river geometry based on sediment size in river bed and bank and the dominant discharge carried by the river over time.

The major cause of change in river regime can be attributed to human activities and interference. Regardless of degree of stability, human activities can produce dramatic change in river regime locally and throughout the entire river. River improvement works by man made river structures can often result in departure from the equilibrium stage that existed prior to construction of these works. The challenge to the river engineer is to understand the hydroogic, hydraulic and geomorphologic balances within a given waterway and the catchments and to design the project within the framework of these balances. Such an approach will generally prove to be more efficient than continually trying to maintain the system against the natural tendencies of a river. River regime is affected by high afflux, deposition of sediments, scouring, flow instability, meandering, bank erosion, outflanking, flooding etc.

2.3 River Stability and Meandering

Inter relation between stream form and bed slope is shown in Fig 5. Accordig to Lane, a river with non- cohesive bed and bank material is predicted to meander if

$$S_0\ Q^{0.25} > 0.00070$$

and braided if

$$S_0\ Q^{0.25} > 0.0041$$

A typical straight river is rarely stable. As shown in Fig.4 , rivers with very small flow of water and sediments, low gradient and velocity, low aspect ratio (Bed width to depth ratio) may be more stable for some distance. Development of lateral instability associated with erosion and deposition on

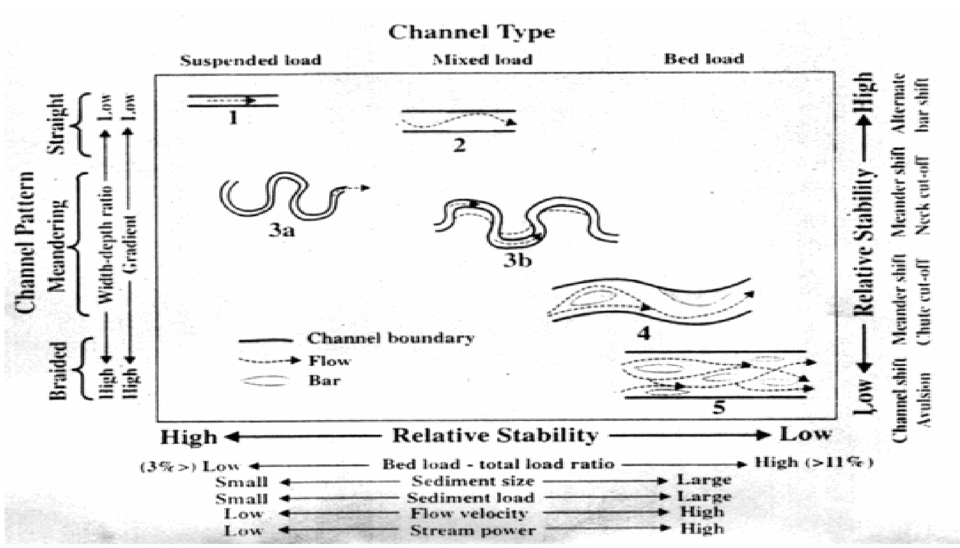


Fig. 4 Interrelation between Channel type, Hydraulic and Sediment Parameters and Relative Stability of Streams

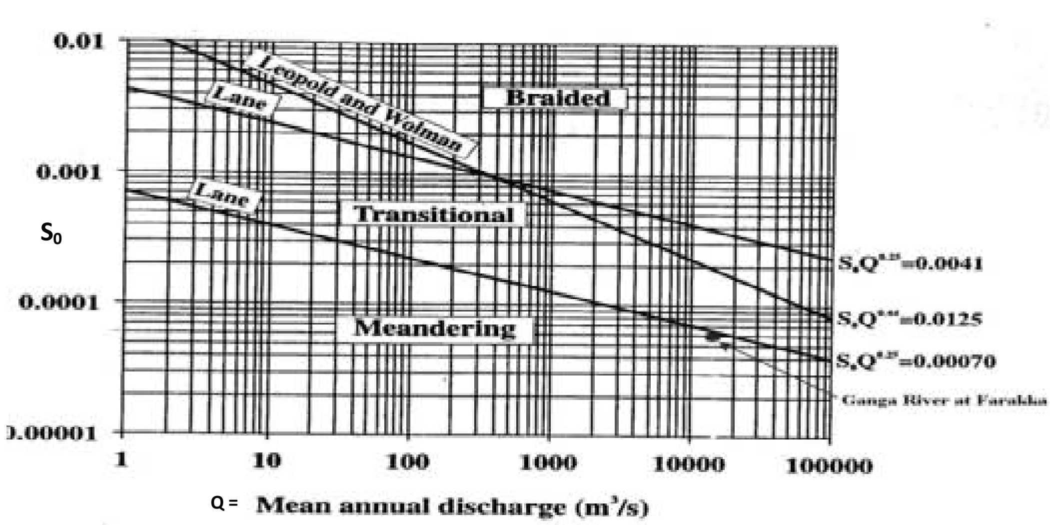


Fig. 5 Prediction of River Rgime from Bed Slope and Mean Discharge

alternate banks give rise to thalweg pattern. Uncontrolled erosion and deposition ultimately give rise to typical meandering pattern. Hickin and Nanson (1984) described the lateral migration rate (M) of a meander by the functional relation

$$M = f(\Omega, b, g_s, h, \zeta_b)$$

Where Ω is stream power, b is a geometric parameter of the river such as width of the river, h is height of outer bank, g_s is sediment transport rate, ζ_b is the erosion resistance offered by the outer bank against erosion. Plotting measured migration rate M (in meter per year) against relative curvature (r/w) (where r is the radius of curvature of flow lines and w is width of stream), Hickins concluded that migration rate is maximum when r/w = 2.5. He derived the relation for maximum migration rate $M_{2.5}$ (in m/year).as:

$$M_{2.5} = \rho g Q S_o / \zeta_b h$$

Where ρ is density of water in kg/m^3, g is acceleration due to gravity in m/s^2, Q is the mean flow rate (in m^3/s), S_o is river bed slope, ζ_b is shear stress inkg/m^2, h is height of outer bank in m. Fig.1 illustrates the typical development of a meander and migration of meander.

2.4 River Behavior in The Vicinity of Bridges

Depending on afflux and normal flow depth , the flow both upstream and downstream of a bridge or a barrage has high non-uniformity (Fig.6) and often found to swing periodically either to the left or right bank (usually main channel flow adheres to either left or right bank) due to their instability. It behaves like a highly turbulent wall jet type flow. Deposition of sediments occur leading to aggradations due to back water effect and loss of stream power upstream. Cross slope develops (because of deposition of sediments on inner bank and scouring on outer bank as shown in Fig.1) resulting in meandering of the river. Immediately downstream of the structure, there is degradation (due to oblique jumps and roller formation, often observed with choking flow condition. Turbulent flow with comparatively clear water (due to sediment deposition upstream) often with choking flow condition flowing downstream with higher turbulence level is also responsible for general degradation immediately downstream of hydraulic structures like bridges.

In a wide Khadir (as observed in most of the rivers in north and north-east India), when there is high amount of constriction of normal flow width (Fig 2), there is aggradations. upstream of hydraulic structures. Such aggradations often result in formation of multiple channels and the main channel flowing along the bank causes scouring. Sometimes, the flow becomes unstable due to long spurs constructed across main channel as a protective measure. Long spurs (designed on the basis of total flood plain / khadir width) may constrict the main channel flow to such an extent, that the flow in the main channel may become unstable and it may swing and directly attack the bank in between consecutive spurs resulting in breaches in embankments and wasting out of the spurs, guide bunds and may outflank the structure. Flow non-uniformity is responsible for meandering, cross-slope and deep scour near banks where the main flow is adhered to. Fig.7-9 illustrate few typical cases of outflanking, meandering and anabranching of flow near some bridges on major and minor rivers.

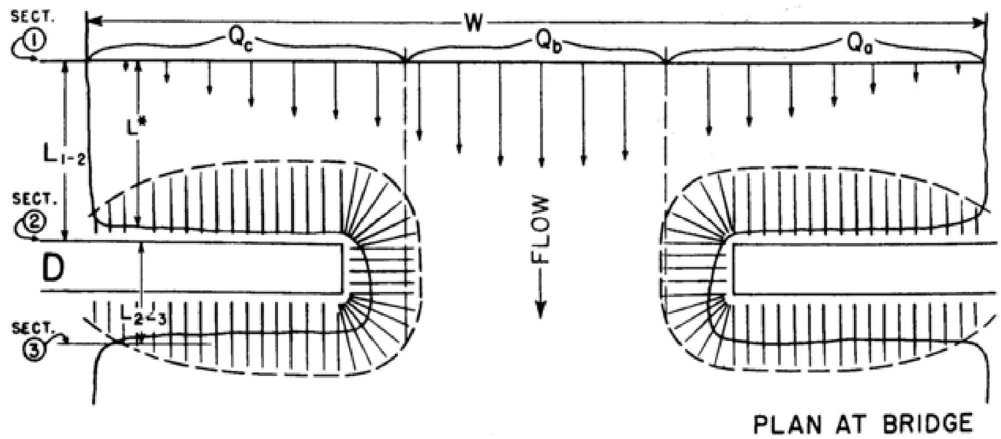


FIG.6 Plan View of a Bridge with non-uniform approach flow (Arrows indicate Velocity)

The figures show only the main channel in the wide khadir. Costly river training measures had to be adopted to save the bridges. Deep erosion occurred near left bank of Ganga river (with its main channel flowing along left bank) upstream of Farrakka barrage. When all the spurs were washed out (Fig.10), porcupines (Fig. 11) were constructed to save left bank subjected to colossal erosion and shifting of river 7 km inside the fertile land of Malda district in West Bengal. Figs. 3(a) shows the disastrous flood in Malda district In West Bengal after breach of marginal embankment about 20 km upstream of Farakka Barrage, Fig.3(b) illustrates the devastation brought about by river Kosi due to change of its course on August 18 th, 2008 due to breach of its left embankment about 12 km upstream of Kosi Barrage.

3.0 NECESSITY AND OBJECTIVES OF RIVER TRAINING

River training is necessary for making better use of river and river water. An untrained and uncontrolled river may bring devastation due to flooding, change in course, braiding, meandering, scouring of bed and banks, breaching of embankments, damages of hydraulic structures, roads and railways etc. Different objectives of river training / river improvement are:

a) Control of floods due to overtopping (spilling) of natural banks.

b) Control of erosion / scouring and breaching of levees / natural banks.

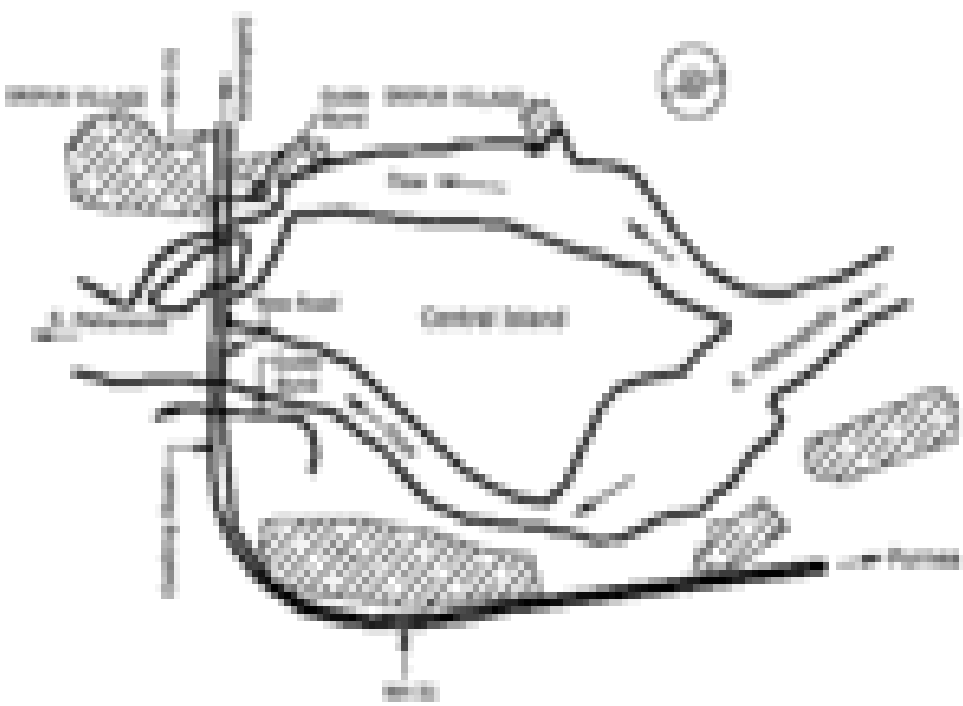
c) Control of meandering and shifting of course, scouring, depositing etc.

river geometry for increasing conveying capacity of both water and sediment flow

d) Improving navigability by reducing flow width and increasing flow depth.

Fig. 7 Outflanking of a vented causeway on the stream 'Danab Khola' Bridge in Nepal

Fig. 8 Erosion on Right Bank of Mahananda River Showing Embayment U/S of the Bridge on NH-31



Anabranching of River Mahananda Upstream of Bridge on NH-31

e) Arrest local scour around hydraulic structures e.g. bridges, barrages, intakes, approach embankments to bridges etc. Improving

f) ontrolling aggradations and degradation of the river

g) Improving flow geometry to avoid oblique flow near hydraulic structures often causing outflanking of the structures.

Fig.10 Washed Out Head of An Impervious 1upstream of Farraka barrage

Fig.11 Porcupines used for Protection Left Embankment Spur in Farakka Barrage

Actually, every river has its individual and unique characteristics. The objective of river training and measures to control it will , therefore, vary from river to river. It is essential to make an in depth study of the river behavior before deciding the necessity and type of river training measures to be adopted.

4.0 DIFFERENT TYPES OF RIVER TRAINING MEASURES

As already discussed under section -1, types of river training measures depend on its valley setting. Broadly, all river training works are engineering measures adopted to guide and stabilize the river in its own course without causing harm / damage to life and properties by controlling flow of water and sediments with a view to make best use of the river and river water. Different types of river training works in common use are briefly discussed in the following subsections:

4.1 Embankments/ Levees/ Dykes

An embankment (also called levees and dykes) is constructed almost parallel to river bank and sometimes normal to the bank, (as in case of approach embankments in wide khadir, connecting hydraulic structures e.g. bridges and barrages) for the purpose of protecting adjacent lands and habitats from flooding due to overtopping and spilling of banks by flood water. They help in channelising the river in a given course with adequate flow depth for navigation and reclamation of land. Further details about embankments / levees and their planning, layout and design criteria are given in IRC-89 (1989) & IS- 12094(2000)

4.2 Revetments / Pitching / Rip-Rap / Mattressing

The most popular measure to prevent river bank erosion against high velocity of flow is to pave the river side banks / embankments with artificial revetments/ mattresses made of either loose and crated stone pitching laid over graded filters (or geosynthetic textiles) to prevent erosion of bed and bank materials. Articulated concrete blocks / brick blocks / asphalt concrete blocks, geosynthetic bags (filled with sand / debris) geo-tubes etc. are also used for lining. Further details about revetments, their sizes, thickness etc. are given in IRC-89 &IS 14262(1995).

4.3 Spurs/ Groynes

Spurs / groynes - both permeable and impermeable types - are constructed transverse to the river bank and extend from bank / embankment into the river either at right angle to the bank (fending spurs) or inclined downstream (attracting spurs) or inclined upstream (deflecting spurs) with the objective of diverting high velocity flow away from the river bank. They also help in dampening of flow and encourage silting of the bank. They help in channelising the river into a defined course in wide flood plains thereby reducing wild meandering, narrowing channel width and increasing flow depth for navigation purpose.

Impermeable spurs made of earth, fly-ash, debris, geo-bags, geo-tubes etc do not allow water to pass through the body of the spur and they deflect flow lines resulting in high concentration of flow near spur heads. It becomes very difficult to maintain the head of such spurs due to formation of deep scour holes near their heads, specially when the spurs are of long length. Very often, they are found to settle, crack and get washed out due to flow through the cracks.

Permeable spurs made of wooden or bamboo piles, porcupines, tetra hadrons, trees etc. permit water to flow through their bodies and are helpful in bank protection due to flow dampening and energy dissipation due to production of micro turbulence behind the spurs. Stone spurs made of either loose or crated stones allow some water to pass through their bodies initially. But eventually they behave like impervious type spurs due to trapping of sediments and debris. Low height stone spurs also called bed bars are submersible type, built at interval above mattresses. They help in trapping of sediment and siltation near the bank. Further details about planning, layout, design and maintenance of permeable and impermeable type spurs are covered in IRC-89(1997) & IS 8408(1994).

4.4 Guide Bunds

When bridges and barrages are constructed in the wide flood plain of a river, it is economical to constrict/restrict the flood plain width by providing a single or a pair of guide bunds and approach roads. Guide bunds (Fig.2) ensure that river flows parallel to piers and abutments and avoid any obliquity of flow near the bridge. They also protect the approach embankments on either side and prevent outflanking of the structure. Guide bunds are constructed of earthen dykes heavily protected with stone pitching / crated stone-gabions on the sloping face on river side and both faces near the head and tail ends. Launching aprons are also provided to protect the toe against scouring. Further details regarding planning, layout and design of guide bunds are given inIRC-89 (1997) & IS 10751(1994)..

4.5 Studs/Hard paints

These are wide and short earth spur like structures to hold the bank lines. They are to be protected with stone pitching or crated stones against scouring of toe. They also help in controlling river alignment between two or more fixed points to avoid wild meandering of river near hydraulic structures.

4.6 Cut-offs

Meandering river has a tendency to shift laterally (Fig.1) on the outer bank side (concave side) with time due to secondary current which scour away material on the outer side of meandering bend and deposits the same on the inner (convex side) side of the bend. In this process, curvature of flow goes on increasing with time and the bend becomes sharper resulting in stronger secondary current in the bend. As a result there is more scour and greater lateral shifting, The process continues till there is a formation of natural cut-off and formation ox-boe type lake. There is a lot of head losses in the consecutive sharp bends of a typical meandering river resulting in afflux and rise in high flood level (HFL). Sharp bends deteriorate the navigability of the river. Cut-offs – natural or artificial - help in straightening a river, fall in HFL and improvement in navigability of the river. Further details about cut-offs are available in CBIP (1989) publication “River Behavior, Management and Training” Vol..I.

4.7 Meander Control

One of the primary causes of river erosion is due to meandering flow. As already stated, the outer side of a typical meandering bend goes on eroding whereas bar formation takes place due to silting on the inner bank. With increase in growth of the sand / silt bars, they advance towards the outer bank subjecting it to flow concentration and erosion. In this process river bends migrate laterally towards the outer bank side and sometimes take a new course or may join another nearby stream i.e. flow avulsion..

Pitching / Mattressing / Spurs / Hard points / cut -offs etc. are constructed to arrest erosion of outer bank. Cement-soil grouting, gabion walls, vegetation growth are very effective means of controlling lateral erosion due to improvement of shear strength of the soil. IOWA -vanes developed by Odgaard (1984) is also found to be effective means of meander control. Further details of these vanes can be obtained from literature (Oddgaard,1986).

.Limited dredging of the sediment bars near their advancing / growing heads will also be highly effective for meander control by reducing flow curvature and controlling erosion of outer banks.

4.8 Grade Control

In the hilly /sub-hilly terrain where the river flows in steep slope, erosion of river bed and banks causes serious problem of stability of the adjoining hills, resulting in slips and land slides. Grade control structures e.g. check dams, barrages, toe protection by stone gabions, etc are effective means of erosion control. The energy slope and the stream power reduce due to afflux created by these structures. However, flushing mechanisms /or manual removal of deposited sediments are necessary to make them effective. Such structures are also used for generation of hydropower by converting terrain head for generation of electricity through water turbines and generators. Sediment flow in the river can be reduced considerably through aforestation and mining of stream bed materials in the catchment areas.

4.9 Bandalling

In the delta stage of a river, it starts flowing through a number of channels. Sometimes, the flow through main channel reduces due to shift of flow through adjoining tributaries resulting in reduction in flow depth in the main channel. As the stream power reduces further (due to reduced flow in main channel), the main channel tends to silt up. To improve the navigation facility in the main channel, Bandalling is an effective device. Inclined vanes are installed at inclination to divert the flow from the subsidiary stream to main stream and a favorable streamline curvature is developed artificially for diverting silts away from the main channel towards its offshoot.(CBIP,1989)

4.10 Pitched Island

As already mentioned earlier, many rivers are found to form a number of silty / sandy island (also called chars) upstream of hydraulic structures like bridges and barrages. When such chars form centrally, the river divides into two or more channels (anabranching). In the lean off flood season, the river flow occurs through these branches. Usually, the branches near the banks are found to carry more flow subjecting it to erosion, due to formation of secondary currents in these curved channels with their outer bend towards the bank. River tends to outflank the structure by breaching the approach road./ flood embankment. Central islands can be so curved and pitched (or provided with artificial cut-off) that the flow will tend to move away from the outer bank and forced to flow centrally normal to the hydraulic structure, thereby improving stability and reducing the risk of outflanking(CBIP,1989)

5.0 SELECTION OF RIVER TRAINING WORKS

Unlike a structural or **a** foundation engineer who knows the various modes of failure and is equipped with thorough knowledge of materials for the evaluation of stress, strain, deformation, settlement etc., a river engineer in charge of river training hardly posses any information with scanty or sketchy data available from the site. Time available is also very limited for thorough analysis and he has to take quick decision regarding the measures to be adopted to avoid failure due to erosion or other reasons. _ Any wrong decision may be totally ineffective and being very costly the money spent will . virtually be wasted due to washing out of the wrong protective measures._In such a circumstances, experience of the river engineer is of paramount importance. In the past, a number eminent river engineers like Khosla, Gole, Gulhati et al from India and Lacey(1930), Lane(1957), Blench(1957), Gales, R.(1938) Spring(1903),Inglis(1949) et al from abroad have successfully planned and implemented river training measures which have been successful over time. Using floats and observing movement of debris and other floating materials, they had been trying to understand the river behavior. In important structures, model study was carried out to find the areas likely to be eroded or silted up by observing flow lines, velocity distribution, flow concentration etc and decided about the type of river training measure to be adopted in a given situation.

The subject 'River mechanics and engineering' has developed over the years due to immense contribution made by Lacey(1930), Lane(1957), Blench(1957), Kennedy(1969), Hickins (1984), et al from abroad and Rangaraju(1970), Chitale (1970), (Kothyari (1992), Mittal et al (2003), Garde (2006) et al from India. River behavior is intimately related to both flow of water and sediments. Over the decades, there is a lot of development in both hydrology and hydraulics of sediment transport, which are discussed at length in the CBIP(1989) publication 'River Behavior, Management and Training'..

Besides experience, river engineers must have sufficient knowledge of the subjects e.g.hydrology, hydraulics, river morphology, river mechanics, sediment transport and fluvial stream processes, etc. to understand the river behavior. Every river has its history and possessing historical data of the river behavior in the past, apart from present data, e.g. river section, bed profile, plan view, flow of water and sediments in the river and their variation with time, valley setting, nature of river bed and bank materials etc are essentially needed for selection of type of river training measure. Valuable information to be collected both from near field and far field of a river in the vicinity of hydraulic structures like bridges, barrages, intake works etc will be of great help in the evaluation and decision making regarding types of training measures to be adopted / selected in a given situation. It should be remembered that no general solution can be prescribed since the problems are varied and river specific, since all rivers have their unique behavior, especially near hydraulic structures.

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