DISCUSSION BY : PROF. S.K. MAZUMDER
PAPER : KOSI DISASTER – CAUTION AND PRE-CAUTION BY S.V. CHITALE, PUBLISHED IN ISH JOURNAL OF HYDRAULIC ENGINEERING VOL. 15 NO. 1, MARCH 2009

Dicussor would like to convey his deep appreciation for the paper. In fact Mr. Chitale in an earlier paper (chitale, 1999) wrote on Kosi river predicting possible change in its course. Discusser also had written papers on Kosi (1985) regarding effectiveness of long groynes. Fig. 1 & 2 shows the 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.

Fig. 1 Villagers are transported in army boats following their rescue from Flood waters in Sursur area in Araria district

A villager rests in a hut surrounded by floodwater in Araria, Bihar.

As a corrective measure author has suggested three steps. But the discusser would like to dwell upon another important aspect not finding any mention in the paper. He is of the firm view that an expert committee should be formed by the Ministry of Water Resources (MOWR), Govt. of India, to investigate the possible causes of the breaches in flood embankments. It is surprising that even after such disastrous failures and spending large sum of money in river training, rehabilitation works and compensation for damage to life and properties over the years, MOWR is indifferent to such investigations/enquiry which should be carried out by experts from India and, from abroad, if necessary, in order to prevent recurrence of such phenomena in future. In the following Para, discusser would like to mention about some important aspects in regard to breaches in flood embankments which have occurred in the past not only in Kosi river (u/s and d/s of Kosi barrage) as well as in Ganga river (u/s and d/s of Farakka barrage).on which discusser had written several papers [Mazumder, 2001, 2004a,2004 b]

1. Morphological Aspects

Both the rives Kosi and Ganga flow in wide alluvial flood plains u/s and d/s of the respective barrages on them. It is well known that when a bridge or a barrage is constructed on such wide flood plains, restricting the normal waterway (laterally in case of bridges and both laterally and vertically in case of barrages), there is backwater and the stream power reduces substantially upstream of these structures resulting in deposition of sediments upstream. Course sediments carried by Kosi from its catchment in Nepal (85% of the catchment lies in Nepal) and the fine sediments carried by Ganga (from the Himalayas and north of Vindas) are getting deposited every year u/s of the respective barrages. Such depositions always cause widening of the river for the same flow and a delta like formation occurs upstream. It has been observed that shoals (or chars) get formed. As the sediments are never deposited uniformly across the width, river starts flowing in meandering pattern with flow concentration on the outer bank and deposition on the inner bank of the river, causing erosion of the outer bank and silting of the inner bank. Meanders are not static but migrate both laterally (at faster rate) and along flow (at slower rate).Lateral movement of meandering channels give rise

to flow curvature due to formation of secondary currents. Sharper the curvature, stronger is the secondary current causing more concentration of flow and more erosion of the bed and bank materials. This process ultimately result in the formation of oxbow type lake with natural cut-off. A lot of research study have been made on meanders and flow characteristics in meandering bends (Chitale,1981; Hickin and Nanson,1984; Oddgaard,1986; Rozovsky,1957).

Another important feature observed u/s of the barrage is that river in such wide flood plains flow in multiple channels during off flood seasons in between the shoals (chars). with maximum discharge through the main channel, usually along the outer bends. It is also observed that most of the breaches occur in embankments with bank full discharge when velocity and shear stress concentration are maximum.
Discusser visited some of the breach sites u/s of Farakka barrage about 20km u/s of the barrage at place called Panchanandpur in Malda district in West Bengal.. He could not get any flood discharge data just before the breach . This is due to lack of co-ordination between the barrage authorities (maintaing the barrage) and the state govt. (in charge of river training). But definitely the discharge at which breaches took place was less than the design flood discharge.

2. River Hydro-dynamics

It is a very complex subject, especially when there is river- structure interaction. It is extremely difficult to predict river behavior near bridges and barrages where normal waterway is restricted laterally, vertically or both. Some attempt has been made by the discusser in his few papers on bridges and barrages (Mazumder,2004a; 2008,2009).Although several software e.g. MIKE series, HEC-RAS, HEC-6 etc have been developed over the years, application of these software require large amount of data which are not readily available. Discusser wanted to know from Farakka and Kosi barrage authorities average annual sediment load being deposited, river cross sections, contour plan etc. But nothing was available.

3. River Training Aspects

Flood embankments/marginal embankments in kosi and Farakka are protected with mattress at all vulnerable reaches so that they can withstand the erosive forces due to high velocity/shear stress. As already mentioned, the forces are very high on the outer side of meandering bends (left bank in Kosi and Ganga rivers u/s of the respective barrages).It is customary to construct long imperious type spurs to deflect the high velocity currents away from the bank subject to erosion. In both Kosi and Ganga, large numbers of such spurs have been constructed both u/s and d/s of their respective barrages. Yet the breaches have occurred in the embankments on either side. It is extremely difficult to maintain the heads of such long spurs due to very high flow concentration near the head. Stone spurs initially permit some water through their bodies. But with time, they also become impervious due to trapping of sediments and debris carried by the river. Discusser has personally observed the progressive failure of such long impervious spurs starting from head in Farakka. Another important parameter causing failure of spurs and mattresses is due to the winnowing process when fine materials in the bed and bank are entrained by high velocity turbulent flow, unless proper filter is used above the base material. Spurs/mattresses settle down due to winnowing, then crack and there is direct flow through the body resulting in washing out of the spurs/mattress.
When the discusser asked the Farakka barrage authorities about the measures taken to prevent winnowing, they mentioned that all stone crates (1mx1mx1m) have been tied with a layer of Assam bamboo skin mat (known as tarza mat). When asked whether sieve analysis was made to ascertain d_{50} size of base materials and any testing was done to ascertain the fitering property of Tarza mats used, no such data were available. Discusser also drew attention to the fact that when crated stone blocks tied with tarza mat are sunk from water surface, there will be innumerable joints both laterally and longitudinally through which fine base materials will escape.
What was apprehended exactly happened. The mattresses about 60 long and 1m thick laid normal to river bank along with crated stone bed bars (60mx3mx3m thick) got washed out and the breach occurred at Panchanandpur where the river Ganga has eroded left bank and moved 7km inside Malda district in West Bengal causing unimaginable loss of properties, agricultural lands and sufferings of the people. Project authorities constructed nine numbers of retired embankments, one after another, but all of them got washed out. Damages that occurred in.1998 flood alone (similar damages had occurred several times after barrage construction) can be assed from the two photographs given below (Figs.3&4)

Fig. 3 Innundation of Agricultural and Mango Trees in in Malda District in West Bengal i

Fig.4 1998 Flood water destroying Properties in Malda Town under 4m depth of water

Permeable spurs made of piles or porcupine etc with permeability not less than 30% and not more than 50%, properly designed and constructed (Lagasse, 1995), have been found to be highly effective in controlling bank erosion due to dissipation of energy in the micro turbulence, As the flow passes through the body of the spurs, there is hardly any flow curvature and concentration of flow near their heads.(Mazumder,2008). After making several correspondences, CWC authorities finally switched on to porcupine type permeable spurs ,as shown in Fig.5 .Results obtained are very encouraging.

4. Weights of Stone Gabions used for Protection Bank and Launching Apron

One of the most important aspect of protective measures of bank and its toe is to use proper size stones in sloping bank and launching apron (used for toe protection

Fig. 5 showing one row of Porcupines used for bank protection upstream of Farraka barrage.

Critical tractive stress method of designing embankment slope for stability must replace the age old conceps of Lacey,s method of design. IRC and BIS codes must be updated in this respect. Mr. Chitale in his paper (2008) points out the discrepancies between the IRC and BIS codal provisions in the design of stones, particularly for the stone laid on horizontal launching apron, Launching apron is hardly used in USA. In India, design of length and thickness of apron is based on Lacey's regime theory. This requires more in-depth study and quick determination of flow distribution, bed profile, turbulence etc. Use of ADCP with GPS is very useful as it gives very fast results and will help in proving the physical model.

In a recent meeting of BIS (WRD-22), discusser was requestad by the members to go through Chitale's paper and examine which of the formulae prescribed in BIS an IRC codes should be used to find weight of stones, especially in launching apron since the weight as per IRC code is found to be about five times more than that in BIS codes . Discusser has already submitted his reports which is now under wide circulation for observation by experts. Summary of stone size and weight obtained by different methods .are given below under identical flow conditions.

Size and weight of stones in sloping and launching aprons

	Sloping Apron		**Launching Apron**			
Method	**D in cm**	**W_S in kg**	**D in cm**	**W_S in kg**		
IS method	21.0	13.0	21.0	13.0		
IRC Method	25.4	22.6	37.5	76.0		
Pylarczyk	16.8	6.57	--	--		

5. Flow stability aspects

When a river flows unrestricted in a flood plain carrying water and sediments form its catchment, it tries to maintain a regime or stable channel, which requires long years to attend. Hydraulic structures like barrages and bridges alter the regime state. A new set of meanders develop upstream and downstream of these hydraulic structures which act as fixed/inflection point. Due to restriction of water way, there will be always afflux. A lack of proper dissipation of energy and above all the imbalance between the incoming and outgoing sediments create new boundary conditions. Discusser (Mazumder, 2000) made in-depth study about the flow stability problems due to sudden restriction of water way followed by sudden expansion. It was observed that up to a maximum of about one third of the normal flow restriction, eddies developed on either sides were symmetric and the flow diffused to its normal width in a short distance downstream.. When the restriction was more than one third, eddies became unsymmetrical and at a very high restriction the flow did not diffuse at all downstream, forming wall type jet flows. It took a long length for flow diffusion with wall type jet flow. The flow attended normal condition, as in unrestricted structure, till the jet entrainment stopped after long distance downstream.. It had been also observed that there was high degree of flow instability downstream and the jet flow may swing periodically from one bank to the other.

Such condition may occur when main channel flow occurs through one of the multiple channels found upstream of the bridges/ barrages. If the length of spurs exceeds one third of the width of the main channel (at bankful discharge), such instability of flow may set in downstream of the long impervious spurs as used in Koshi and Ganga rivers upstream of the respective barrages. Once the flow becomes unstable due to high restriction of main channel flow, it will take sharp turn from the head of the spurs and behaves wildly. It may move towards the embankment almost normal to the embankment. Thus, the main channel flow is likely to directly hit the embankment in the reach lying between two consecutive spurs. No embankment can withstand such direct flow attack and is bound to fail..
Discusser has strong apprehension that in the design of long spurs across main channel., such situation is never envisaged. It is interesting to note that embankments failure occurred in the zone llying between consecutive spars in both Kosi and Ganga rivers upstream of there respective barrages. Length of spurs should, therefore, be decided not on the basis of flood plain/khadir width of the river but on the basis of flow width of the main channel adjacent to the river bank in order to avoid such kind of flow instability. Use of permeable type spurs made of porcupines or piles , duly protected with GI wire crated stone gabions and laid over geosynthetic textiles with adequate overlap, are strongly recommended to prevent such unstable flow conditions leading to embankment failure.

REFERENCES

Chitale, S.V., Future of Kosi river and Kosi project, J. of Instn. of Engrs(I), vol.81, Dec.,1999

Chitale, S.V. (1981), ": Shape and Mobility of River Meanders" Proc. XIX Congross of IAHR, Vol. 2, pp 281-286, New Delhi

Chitale,2006 Improvement in design practice of side slope protection of guide bunds for bridges J of IEI, vol67, May 2006

Hickin, E.J. and Nanson, G.C. (1984) "Lateral Migration of River Bends" J. of Hyd. Engg. ASCE, Vol 110, No. 11, pp 1957-67

Lagasse,P.F., Schall,F. Johnson, F., Richardson, E.V. and Chang, F.,(1995), Stream Stability at Highway Structures, Department of Transportation, Federal Highway Administration, HEC-20

Mazumder, S.K., Training river Ganga near Farakka barrage, Proc. of national conf. On hydraulics and water resources HYDRO-2001, org. by ISH and CW&PRS, Pune, Dec.2001

Mazumdar S.K. (2004a), "River Behaviour Upstream and Downstream of Hydraulic Structures" Proc. Int. Conf. on Hydraulic Engineering : Research and Practice (ICONHERP-2004), organized by Deptt. of Civil Engineering, IIT, Roorkee, Vol. I, P.253-263 in honour of Prof. K.G. Ranga Raju.

Mazumder,S.K(2009).River behavior near a bridge with Restricted waterway and afflux- some case studies Paper accepted for publication in the J. of IRC , New Delhi

Mazumder,2008 Training river near a bridge with particular reference to river Bagmati crossing NH-57 Paper presented at Hydro2008 conf at jaippur and pub in proceedings of Conf.

Mazumder, S.K. (2004b)" Aggradation/Degradation of Ganga near Farakka Barrage", Proc. Seminar on "Silting of Rivers- Problems and Solutions" org. by Min of Water Resources, Govt. of India, New Delhi Feb. 12-13

Mazumder, S.K. "Effectiveness of Impervious type groyens in river bank protection with particular reference to river Kosi in India "Proc. of IInd International Conference on Hyd. Of Floods & Flood Control organized by BHRA (Fluid Engg. Centre), Cambridge, England, Sept. 24-26, 1985

Mazumder, S.K. and Pramod Kumar, "Sub-critical Flow Behavior in a Straight Expansion" ISH Journal of Hydraulic Engineering, Indian Society for Hydraulics, Vol. –7, No. 1, March 200

Ordgaard, A.J. (1986), "Meander Flow Model 1: Development" J. of Hyd. Engg., ASCE, HY-12, pp 1117-1136

Rozovski, J.L. (1957) "Flow of Water in Bends of Open Channels" Acadamy of Sciences of the Ukranian SSR,. Translated in English by Prushansky, Y. Israel Programme of Scentific Translation.