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AN OVERVIEW OF RIVER TRAINING WORKS ALONG THE BANKS OF RIVER BATA AND SWAN, HIMACHAL PRADESH

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***Abstract*— River training works plays an important role in flood control and bank erosion problem. Many techniques are used as engineered solutions to the problems. This paper describes the structural mitigation measures in terms of channelization of River Bata and Swan and their tributaries by construction of embankments at place which are prone to riverine and flash floods and is essential for the inhabitants who are affected every year due to flood havoc. The Geotextile filter materials used in embankments for erosion control and flood protection works were tested at CSMRS, New Delhi as a quality check programme. The paper briefly presents the overview of problems and the remedial works carried out along the various reaches of Bata and Swan River.**

Keywords— **Flood Protection, Erosion, Geotextile filter, Quality control**

I. INTRODUNTION

Among the various natural hazards, floods and river bank erosion are the most common and quite devastating. Like, earthquake and volcanic eruptions, they also affect human activities in various ways wherever they occur. Erosion, transportation and deposition are the main functions of a river. Through these activities, it creates different landforms and brings about changes in its course. When it overflows its banks, it creates natural calamities, like flood, erosion and sedimentation, which adversely affect human occupancies of the floodplain. Erosion has been a part and parcel of the flood hazard. There may be heavy bank erosion during and after the flood which will lead to bank line migration. Bank erosion is a geomorphic process which changes the channel dimensions by lateral widening. Generally bank erosion is a process commonly associated with migrating meandering streams or laterally shifting streams. Migrating streams tend to erode the banks and widen the channels by undercutting and bank caving; the eroded material is then washed away by the flow.

The State of Himachal Pradesh is mainly prone to riverine and flash floods due to special characteristics of rivers which flows in mountainous areas and hence are called as hilly rivers. Bata and Swan River in Himachal Pradesh, have narrow and steep bed slopes. The rise of flood in them is very sudden and flashy which overflows the banks during monsoons and causes severe soil erosion, landslide, deposition of sand on fertile land and damage to life and property. The upstream catchment of hilly river consists of mixture of boulders, gravels, shingle & sand and makes them behave distinctly when compared to normal meandering course in the downstream areas carrying sand and silt. Due to continuous silting, the bed of hilly rivers rises constantly due to which meandering action takes place. Training works for these rivers become necessary to control flood, erosion and sediments to manage the river to flow smoothly in required direction.

Structural mitigation measures adopted for channelization of River Bata and Swan and their tributaries is by construction of embankments at place which are prone to flood. The river channels are confined by providing a pair of embankments or training the rivers into a well defined stable channel.

II. NEED FOR WORK

The entire region of Himachal Pradesh forms catchment of rivers like Yamuna, Satluj, Beas, Ravi and Chenab, which flow through its territory to plains and carry a very heavy load of silt. The paths that these rivers and their tributaries traverse are having steep slopes causing thereby high velocity and

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erode much of the cultivable lands. The population also gets effected as houses and agriculture lands often get submerged or washed off. The losses due to flood include, human life, Cattle heads, crops damage, agriculture land damage due to spread of sand in the inundated areas, damage to flood protection works and damages to public utilities such as roads, bridges, water supply schemes, irrigation schemes, electricity and telephone lines etc. Flood protection works in the shape of channelization of the rivers and their tributaries by construction of embankments, spurs etc. at places which are prone to floods is essential for the inhabitants who are affected every year due to flood havoc. The total geographical area of the State is 55.70 lac hectares and net cultivable area is 5.76 lac hectares. According to a rough estimate, about 2.31 lac hectares of area in the state get affected by heavy floods. There is an immediate need for providing flood protection works in most affected flood prone areas along Bata and Swan Rivers.

III. BATA RIVER FLOOD MANAGEMENT PROJECT

A. **The Bata River System –**

Bata river emerges near by the village named Phandi Bodiwala in G.P. Kolar, Tehsil Paonta Sahib District Sirmour, Himachal Pradesh and and passes through number of villages namely Kolar, Sukhchainpur, Dhaulakuan, Bherewala, Tokion on right bank and Phandi Bodiwala, Bharapur, Rampur & Gunglon on left side and merges in River Bata which ultimately merges in River Yamuna. The Bata River keeps on changing its course in rainy season damaging the fertile land of above villages during flood and is further influenced by the fall race water of Giri Bata Hydel Project, which adds nearly 16000 Cusecs of water and it results ultimately the erosion of land on both the banks of river..Over the years, Bata River has been causing damage to the life and property of the inhabitants located on the banks of Bata River.

B. Problem Description –

In summer, Bata River remains almost dry up to R.D. 8300 m but when rainy season starts the discharge of river increase abruptly due to the typical catchment area of this river. The rainy water creates havoc in this area by eroding fertile land, damages crops; endanger human lives, live stocks and houses. The behavior of this River is unpredictable because the banks restricts/confine the flow of River to a narrow space. This enormous quantity of water causes turbulence which is dangerous for the stability of the river banks. The excess flow of water is also due to deforestation of this catchments area since years, excessive grazing due to increasing cattle population is also resulting in too much runoff, causing flash floods in the River.

As there is no other source of income to the inhabitants of the valley except agriculture, hence this erosion of their land is causing great concern, if the erosion is not checked in time many villages may face extinction and people may have to migrate to other places.

C. Bata River Flood Management Programme –

Keeping in view the serious threat posed by Bata River to the villages situated on the banks and in order to provide protection to the people, the Himachal Pradesh Government has proposed to channelize tributaries of Bata River Phase–I (Sunkar) from RD 0 to 8300 m **i**n Tehsil Paonta Sahib Distt. Sirmour (HP). Sunkar is the main tributary of River Bata. The scheme will protect 584.60 hectarea valuable cultivable lands, houses, orchards and other valuable properties. The benefit cost ratio of the project is 1.49:1.

D. Solution Implementation work–

Embankment: Embankment is provided on both side of River at various RD's where flood protection is urgently required. The side slope of the embankment is 2H: 1V in the back side of embankment, with stone pitching and wire crates launching apron. On water face side slopes has been proposed with dry stone pitching over Non-woven Geotextile filter. Sand 15 cm thick is placed under and over Geotextile for making the embankment surface smooth and to avoid any damage to Geotextile filter. Wire crates are made up of 5 mm thick G.I wire of 15 cm x 15 cm mesh size filled with boulders of approved quality and weight not less than 18 kg packed tightly with sloping faces of protection work. Keeping in view the erosion of the banks, pitching and launching apron are required in the entire length. The total length of embankment is 11650 m. The top width of the embankment is 3.00 m and height 2.50 m with free board of 1.0 m.

Fixation of bank spacing: One of the most important problems in the flood conferment is to ensure the safe passage of flood waves between the banks with minimum disturbance on the regime of the River. The total length along which the levees has to be provided has been divided into three parts as per slope of bed and spacing kept as 180, 195 & 230 m. Where the River is wide it is kept ever more than required width as per site conditions (IS 12094-19847). To achieve the minimum required width of flow of water as per sire requirement, the spacing is kept 1.50 times the Lacey's width. However adjustment of the spacing is done to suitably align the embankment on the ridge of the natural banks of River, where land is high and soil is suitable for the construction of embankment.

Channelization of confluence points with Bata River: In addition to above, tributaries entering into the Bata River at various RD's with huge discharge during rainy season at confluence point are also channelized which ensure that water

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will not damage the embankments of main River and will enter at the defined point in Bata River.

IV. SWAN RIVER FLOOD MANAGEMENT PROJECT

A. **The Swan River System –**

Swan River originates from Joh-Marwari Village near Daulatpur Chowk in tehsil Amb of District Una and flows through the inter mountainous valley dividing district longitudinally and finally joins the river Sutlej near Anandpur Sahib in Punjab almost 20 km downstream of Santokgarh bridge. Una District is surrounded by the low to medium Shivalik hill ranges of Kangra, Hamirpur and Bilaspur District of Himachal Pradesh on North and East side and low hill ranges of Hoshiarpur and Roper District of Punjab in West and South side (Fig.1). The total area of Himachal Pradesh is 55673 Sq km out of which District Una cover 1540 Sq km in the Himalayan foothills. The total population of Una district is 4,48,273 (Census-2001). The total length of Swan River is 85 km, out of which 60 km falls in Himachal Pradesh.

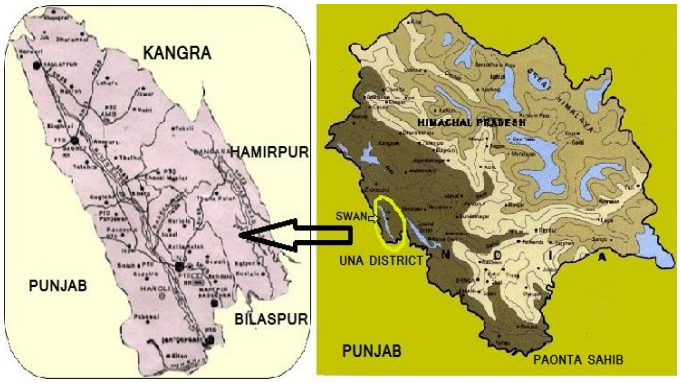

Fig. 1.Map of H.P. showing Una District & Swan River

All the Khads in catchment flows almost in East-West direction are meeting Swan on left bank & Khads flowing West to East- North are meeting Swan River on right bank. The Swan flow in low lying Shivalik hills, with a sinuous path from NW to South direction. All the Khads are rain fed, but contributing some flow from spring sources in the catchment areas. The Khads generally have very low flow during summer & winter months. There are 60 major tributaries of Swan River which joins Swan on the left and right banks in a length of 60 km. The width of river being less than one km at start and extend upto 4 km in between and at end point before its confluence river Satluj.

The total catchment area of Swan River is about 1400 sq. km. out of which 1200 sq. km. falls in the Una District and rest in Punjab where it joins Sutlej. The area forms the part of lower Shiwalik hills, consists of fragile rock, highly prone to erosion. Altitude of the catchment varies fromRL+ 975.00 m in hilly area to RL+335.00 m at Santokgarh Bridge. The slope of the river varies 10 m/km at start to 1 m/km near Santokgarh Bridge. The catchment area having 20% forest land consist of bushes and scanty forest, 30% agriculture and 5% used as pasture land and rest 45% is unused or habitat/urban land.. The Catchment area experience medium to heavy rainfall during monsoon and tributaries of Swan contributes significant discharge to Swan River. The discharge of Swan increases with its travel from the source. The steepness of tributaries generally increases from the confluence toward upstream. It varies 1.5 m/km near confluence to 18 m/km in the upstream. The width of the tributaries area varies from 40 m to 200 m and length varies 2 km to 21 km. The tributaries joining the right bank of Main Swan are more in numbers (34 nos.) and smaller in size, whereas tributaries joining from left bank are less in number (21 nos.) but large in size.

B. **Problem Description –**

Generally floods are expected every year. The main havoc occurred during the year 1988 and 1995, where whole district was very badly hit by heavy rainfall & the flash floods. The intruder floods had eroded the tributaries banks, which resulted to heavy landslides, huge erosion to cultivated land, damages to roads, culverts, irrigation schemes, houses with 37 nos. human lives and nos. of livestock washed away. Whole area communication was disrupted and District was cut off from rest of the world. Similar kind of flood damages also experienced in the past 12 years in Una & Amb Sub-Division. Table 1 shows the details of damages due to flood in the past 12 years. Flood authorities and public have observed that after the every floods/monsoon season an average 500 hectare of land annually congregate to direct erosion, water logging, commercial & industrial land remain under the threat of floods. The floods wash away and uproot the standing crop and subsequently deposit the gravel, silt and unfertile soil on agricultural land which result in damage of standing Kharif crop and eliminate the possibility of growing Zaid crop.

The central part of the Jaswan-Dun valley having alluvial and fertile fields, river terraces and small clay hills of recent age. The Shivalik ranges having sand stone, gravels, sandy soil and conglomerates. The surrounded Shivalik ranges experience heavy rainfall during monsoon period and the rainwater flow from hills contribute to cruel floods in various tributaries of Swan River. These floods bring gravels, residuals of vegetation and huge silt from the hills to plain area. The every year heavy floods in tributaries create siltation, erode banks and enter into the valuable fertile land, industrial area and in commercial establishments. The peoples residing along the tributaries and main Swan always remain under threat of floods in monsoon period. Continuous erosion of cultivated land and deposition of eroded material to relatively plain area create the siltation problem in the tributaries and raising its bed level, resulting to meandering nature of tributaries.
Swan River is known as “Sorrow of District Una” as it creates havoc during monsoon almost every year due to floods. Approximately,10,000 ha. of agricultural land is effected by

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floods in Swan River and nearly 2000 ha. of fertile land is not being cultivated due to fear of floods. Agriculture is only means of earning livelihood for the majority of population of Una. Hence Socio-economic status has got the worst set back in past, due to floods in Swan River.

Table -1 Details of Damages due to flood in the past 12 years (1998 to 2010) from Daulatpur to Santokgarh Bridge

SR. No	Details	Total (Nos.)	Amount in Lacs
A	Village affected	165	
B	Population affected (Census-2001)	235834	
C	House Losses		
a)	Katcha	10230	20460
b)	Cow shed	10424	10424
c)	Pucca	2352	11760
D	Other Losses		
b)	Live Stock	599	119
c)	Road	148 km	2220
d)	Bridges	41	820
e)	Water supply schemes	69	1380
f)	Irrigation Schemes	50	1000
	Total		48183
	Avg..Annual Damage		4015

C. Swan River Flood Management Programme –

In the Phase-1st the main Swan River has been provided with embankments on its both banks from Jhalera Bridge (RD 19160) to Santokhgarh Bridge (RD 2500) in a length of 16.67 km. The work of this phase was started in year 2000 and was completed in year 2009. In this phase 2260 hectares land has been reclaimed.

In the Phase-2nd the main Swan River has been provided with embankments on its both banks from Gagret Bridge (RD 47500) to Jhalera Bridge (RD 19160) in a length of 28.34 km. The work of this phase was started in year 2008 and was completed in year 2012. In this phase 5000 hectares land has been reclaimed (Fig. 2). Channelization work is extended from downstream of Santokhgarh bridge upto Himachal boundary in Phase-3rd.

Fig. 2.Reclaimed area in Phase-II

Keeping in view encouraging result of Swan Channelization Phase-1st and Phase-2nd the State Govt. decided to extend the Swan River Flood Management Programme in Phase-4th to cover balance reach of main Swan River from Daulatpur bridge (RD 58390) to Gagret bridge (RD 47500), total 10.89 km in main Swan River along with 55 Nos. major tributaries which are joining the main Swan River from Daulatpur bridge to Santokhgarh bridge, so as to get the full benefits of the flood protection scheme. In this phase 7163.49 hectares of land is estimated to be reclaimed. Total 165 Nos villages of Distt Una with population 235834 Nos shall be benefitted from the flood management Programme. Figure 3 shows the executed and proposed Swan River Flood Management Projects. Followings are the main objective of this project:-

a. Saving the crop & Valuable agricultural land.
b. Saving of Industrial units in the area.
c. Saving the commercial land, houses from floods.
d. Saving of human life, cattle's & spreading of epidemic due to floods.
e. Saving of soil erosion, water logging, and siltation in the area on account of floods.
f. Production saving of Industrial units, which stop due to floods & it's after effects.
g. Saving of communication, roads links & Govt. revenue losses due to flood in Swan & its tributaries.

D. Solution Implementation work–

Systematic control & protection measures shall save damages due to floods & safely pass the water to downstream reaches. Construction of embankments on both the banks, RCC boxes & Pipes to drain the local area rainwater etc are the main attempt of flood protection measures to avoid losses. Embankments on both the banks at appropriate spacing prevent the inundation of low laying area during the flashy floods and are based on Lacey's width and embankment spacing kept two times of the Lacey's width in main Swan River and spacing kept upto maximum available width in the tributaries.

Embankment and Apron: Low height heterogeneous type of embankment with Central clay core for seepage control is dressed to an inclination of 1V:1H and local sand/river bed material in outer core of embankment is dressed to a slope of 1V:2H. The surface of embankment is made smooth by placing 15cm thick sand layer. Over this a layer of non-woven geotextile is laid as filter media upto apron portion and anchored at the top & bottom of embankment. Again 15 cm thick sand layer is placed to avoid any damage to Geotextile filter. After placement of geotextile filter slope pitching of thickness 30 cm with stone in 5 mm thick G.I wire crates of size 1.5 m x 1.5 m x 0.30 m up to top of embankment. Apron width kept 6 m in main Swan River and 3 m for tributaries. Thickness of Apron is 0.60 m and laid in two layers of 0.30 m each. Top width of 6 m in all kind of embankments in main Swan River, whereas 3 m top width for all the heights in tributaries. The height of embankment is on the basis of HFL with free board of 1.5 m in Main Swan River and 0.75 m in tributaries. Total length of embankment in flood protection scheme will cover 55 nos. major tributaries: - On right bank of

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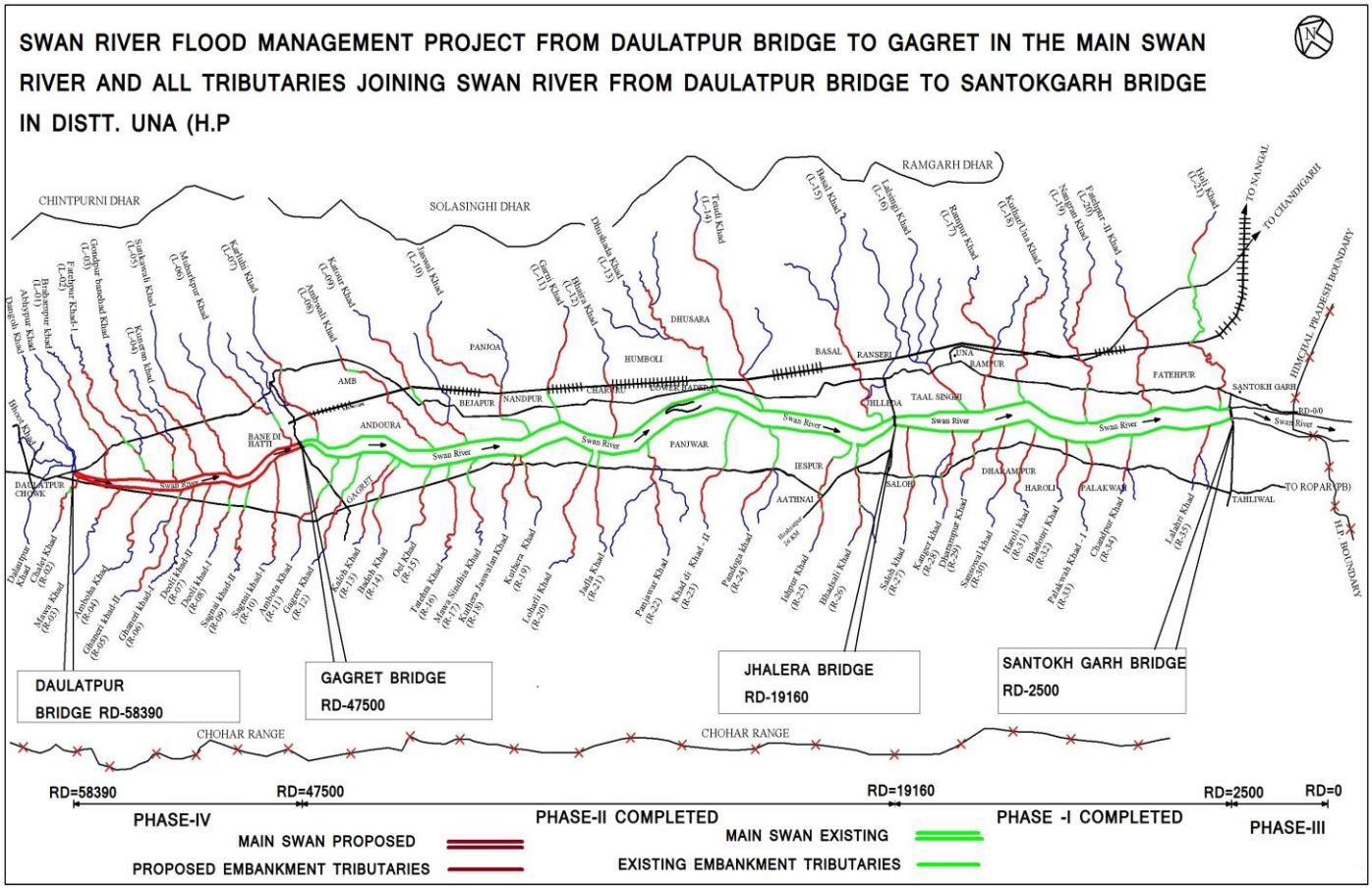

Fig. 3. Executed and proposed Swan River Flood Management Projects

main Swan River, 34 nos. main tributaries, total length =237.60 km and on left bank of main Swan River, 21 nos. main tributaries, total length =272.65 km. Figure 4 shows the completed embankment in Phase-II.

Toe-Wall: Geotextile filter is extended below the Toe wall and side of Toe wall. Sand layer of thickness 15 cm is placed on top and bottom of the Geotextile filter at toe-wall bottom portion. Toe walls made up of stones in G.I wire crates of size 1 m x 1m x 1m all along the length of embankment provided in river side of main Swan & tributaries. Toe walls is also to be provided in the country side for embankment in the main Swan River

Geotextile Fabric Filter: Geotextile fabric filter forms an integral part of protection works. Fixing fabric filter made up of Non-woven Geotextile having minimum mass per unit area of 275 gsm, thickness not less than 2.50 mm manufactured from 100 % polypropylene material is provided below the wire crated apron, stone pitching and toe-wall to prevent soil erosion. Total quantity of Geotextile filter material under use is 22.12 km^2. This filter material replaces traditional granular material which were used in past. For determining the suitability of such specialized material it is evaluated for physical, mechanical, hydraulic and survivability properties at Central Soil & Materials Research Station (CSMRS), New Delhi.

Fig. 4.Completed embankment in Phase-II

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V. LABORATORY INVESTIGATION OF GEOTEXTILE FILTER

As part of the quality check, CSMRS, New Delhi carried out extensive testing for evaluating the properties of Non-woven geotextile filter used in Bata and Swan River. The laboratory tests such as mass per unit area, thickness, Apparent opening size, CBR Puncture strength, Wide width tensile strength (wrap & weft), Grab tensile strength (wrap & weft), Trapezoidal tear test, Water Permeability and cone penetration test were carried out on the above materials received from the Bata and Swan River Flood Management Project. All these tests were carried out in accordance with ASTM standard test methods [6-14]. The tests results [3-5] are presented in the Table 2.

Table -2 Result of laboratory test on Geotextile filter

Properties	Test Results
Mass per unit area, g/m^2	275
Thickness, mm	2.5
Apparent Opening Size, mm	0.150 - 0.200
Permeability, lit/m^2/sec	150 - 160
CBR Puncture strength, N	3850
Wide Width Tensile Strength kN/m -Warp & Weft	17.50
Grab Tensile Strength, N	1100
Cone Penetration, mm	15
Trapezoidal Tear, N	450

VI. SELECTION OF GEOTEXTILE FILTER

Geotextile filters are used between the soil and drainage or armoring medium. Drainage media include natural materials such as gravel and sand. For selecting good quality filter media study of drainage medium is required to know whether retention or permeability is the favored filter characteristics

A filter should prevent excessive migration of soil particles while at the same time allowing liquid to flow freely through the filter layer. Filtration is therefore summarized by two seemingly conflicting requirements. Figure 5 Shows bridge and clogging formation

1. The filter must retain soil, implying that the size of filter pore spaces or openings should be smaller than a specified maximum value; and
2. The filter must be permeable enough to allow a relatively free flow through it, implying that the size of filter pore spaces and number of openings should be larger than a specified minimum value.

In addition to retention and permeability criteria, several other considerations are required for geotextile filter design. Some considerations are noted below:

Survivability: Ensures that the geotextile is strong enough to resist damage during installation.

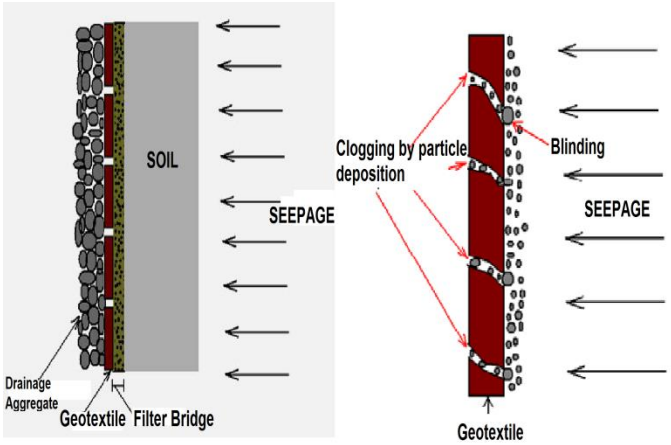

Fig.5 Filter bridge formation and method of clogging & blinding

Durability: Ensures that the geotextile is resilient to adverse chemical, biological and ultraviolet (UV) light exposure for the design life of the project.

Retention: Ensures that the geotextile openings are small enough to prevent excessive migration of soil particles.

Permeability: Ensures that the geotextile is permeable enough to allow water to pass through without causing significant upstream pressure buildup.

Anti-clogging: Ensures that the geotextile has adequate openings, preventing trapped soil from clogging openings and affecting permeability.

As per IS 14262: 1995 the following criteria, depending on the gradation of bed material, may be used to select the correct filter fabric:

1. For granular material containing 50 % or less fines by weight, the following ratio should be satisfied.
   $$\frac{\text{85\% passing size of bed material (mm)}}{\text{Equivalent opening size of bed of fabric (mm)}} \geq 1.0$$
   In order to reduce the chances of clogging, no fabric should be specified with an equivalent opening size smaller than 0.149 mm. Thus the equivalent opening size of fabric should not be smaller than 0.149 and should be equal to or less than 85 % passing size of the bed material.
2. For bed material containing at least 50 % but not more than 85 % fines by weight, the equivalent opening size of filter should not be smaller than 0.149 mm and should not be larger than 0.211 mm.
3. For bed material containing 85 % or more of particles finer than 0.074 mm, it is suggested that use of non-woven geo-fabric filter having opening size and permeability compatible to the equivalent values given in 1 above may be used.

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VII. CONCLUSION

This paper gives an overview of river training works executed by H.P Government. Based on the initial success achieved, the methodology is adopted in phased manner to cover balance reach of the River so as to get the full benefits of the flood protection scheme. No doubt, that the initial cost of the project is on the higher side, even then it will cost less in the long run considering the high benefits yielded in the form of saving agricultural land, private & public properties etc. which will certainly boost the economy of the state.

Conventional graded filter materials like earth and boulders etc were used in the past for construction of embankments and bank protection works. But satisfying the filter & drainage criterion for conventional graded design is extremely expensive, difficult to obtain, time consuming to install and problem of segregation during placement. The conditions can easily and cheaply be achieved using a Geotextile filter to perform filtration. To keep this system to perform in the long run, it is necessary that Geotextile filters retain soil particles and prevent erosion while at the same time allow water to pass freely. Buildup of hydrostatic pressures in protected slopes is prevented, thus enhancing slope stability. The use of stone fill G.I wire crates of appropriate size give stability to apron, stone pitching and toe-wall construction

Following advantages of using Geotextile filter can be outlined

- Geotextile filter layer causes lower environmental impacts compared to conventional gravel based filter layer.
- Convenience in laying, easy to install and better control over quality.
- Geotextile filter is easy to obtain, it takes less time in procurement than the boulders & aggregates and also length of carriage distance. Therefore huge cost for carriage would be saved.
- Geotextile filter is manufactured from machine process there uniformity in material specification can be achieved and maintained for the entire project.
- Conventionally used gravels/boulders for protection works has become scarce and also damage the ecological balance. Using of geotextile filter is found perfect replacement for gravels/boulder.
- Such type of application of geotextile filter where it forms an integral part of protection works replaces all other methods for immediate protection in the region where flood is a regular phenomenon and construction is to be completed in a constraint time period.

Considering the advantages of Geotextile filter in comparison to conventional materials there is a huge requirement in the near future and role of quality control and assurance should therefore be emphasized to ensure that the Geotextile filter material being used meet the minimum qualifying criteria.

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