Journal of Civil Engineering and Environmental Technology
Print ISSN : 2349-8404; Online ISSN : 2349-879X; Volume 2, Number 9; April – June, 2015 pp 58-62
Krishi Sanskriti Publications
http://www.krishisanskriti.org/jceet.html

Design of embankments and bank protection works for hilly rivers

Naveen Naidu Maddukuri[1], N.V.N.Ravali[2], A. D. Vasudeo[3]

[1]*Master of Technology*
Visvesvaraya National Institute of Technology
[1]*Email ID: vimpnaveen1234@gmail.com*
[2]*Master of Technology*
Visvesvaraya National Institute of Technology
[2]*Email ID: ravali.venkatanaga@gmail.com*
[3]*Assistant Professor*
Visvesvaraya National Institute of Technology
[3]*Email ID:advasudeo@civ.vnit.ac.n*

Abstract: *Hilly rivers have narrow and deep cross sections with very steep bed slopes. The rise of flood in them is very sudden and flashy. Some of the Hilly Rivers overflows the banks during monsoons and causes severe soil erosion, land slide, deposition of sand on fertile agriculture and damage to life & properties. Due to continuous silting, the bed of hilly rivers has risen constantly due to which meandering action takes place. Training works for these rivers are taken up to control flood, erosion and sediments to manage the river to flow smoothly in required direction. Hence, it is necessary to adopt the suitable training works, monitor the performance of the structures and to plan further training of the river courses. In the present study the flood embankments and bank protection measures are designed for hilly river in different reaches by using predicted water levels for 100 years return period. Predicted water levels are used to finalize the top level of the embankments by adding sufficient free board (say 1.5 m or 1.8 m) in the vulnerable reaches. The higher velocities and discharge intensities would possibly induce higher scour near the toe and erosion of the embankments. In view of this it is suggested to protect the embankments by providing proper bank protection works and launching apron at the toe.*

Keywords: *water level, flood embankment, velocity, free board.*

1. INTRODUCTION

Steep gradient is one of the distinguishing features that give special characteristics to rivers which flow in Mountaneous areas and hence are called as hilly rivers. Also hilly rivers are characterized by the presence of variety of sediments which consists of mixture of boulders, gravels, shingle and sand. These rivers, moreover, differ considerably from those carrying sand and silt. This presence of special sediments in the hilly rivers makes them behave distinctly when compared to normal meandering courses. Deep well-defined beds and wide flood plains, Boulder Rivers tend to have straighter courses. During a flood, the high velocity flow transports boulders, shingle and gravel downstream, but as the flood subsides the flow of materials when checked gives beds with materials piled in heaps. The flow in hilly rivers increases abruptly and experiences flashy floods. The intensity of flashy floods has aggravated resulting immense damage to the life, crops and property.

River training works for these rivers are taken up to control flood, erosion and sediments to manage the river to flow smoothly in required direction. River training involves construction of structures across or along a stream like levees or embankments for flood control and protection. These structures such as spurs, guide bunds (Bunds guiding the flow) etc are to be constructed. The most commonly used way of flood protection is to provide embankments with or without spurs which protect the banks against possible sediment laden river attacks. Also can be supplemented by the retired embankments wherever, the river attack is severe. The river channel can be confined by providing a pair of embankments or training the rivers into a well defined stable channel.

1.1 Types of flood protection works

- Construction of flood embankments along the river banks or ring bunds around important towns, villages, properties and estates to prevent flooding.
- Suitable protective fenders of concrete, rolled steel or rails may be provided upstream of the bridge to reduce the impact on piers and abutments due to rolling boulders.
- The formation of gullies by the water coming down the hills can be prevented by afforestation, construction of gully/ check dams, contour bunding, debris basins, chambers or wells. These should be cleaned as frequently as necessary
- Suitable slope protection with boulders or concrete slabs and boulders in wire crates forming flexible type apron may be provided are efficient in arresting the high velocity flow approaching the embankment
- The most common in - stream control flow structure, including cross vanes ,J-hook vanes, rock vanes, W weirs, submerged vanes, stream barbs, bend way weirs,

spurs, and constructed riffles also suitable for provide bank protection and channel stabilization along with the potential for ecological enhancement (R. R. Radspinner, A.M.ASCE etc)

- During the floods the materials such as boulders, pebbles, tree and its branches collect near upstream of existing bridges. These materials should be removed periodically to avoid inundation due to constricted waterway of bridges.
- Preparing detailed plans for mobilisation of the local resources for supervision of embankments during floods, for flood relief works and other emergency measures and to associate local populations with such works by way of Shramdan (community participation) etc. Collection of materials such as sand filled bags, stones, brush wood mattresses to reinforce or add to the protective works during flood
- Flood forecasting and warning system to keep alert all concerned people in advance and to take timely action for evacuation in case of imminent danger.

The object of a flood protection study is to decide which of the above works are most suitable, and their location, size, design and costs. Associated with this is, a socioeconomic study to determine the potential damages headed off by the protruded training works, and whether they justify the benefit-cost ratio. Designed Flood protection works may threaten by floods against a future “Maximum Probable Flood". In present state of our knowledge, no exact quantitative value can, however, be assigned to this entity, but there are various methods of approximating it. Suitably one of the above can be adopted for particular flood more or less ascertain results as socioeconomical.

2. PROBLEM STATEMENT AND STUDY AREA:

Swan river is one of the tributary of the River Satluj has catchment area of 1204 Km^2 in Una district of the Himachal Pradesh. It has a length of 65 kms in Himachal Pradesh. The study area includes Swan River from Babehar khad to Raipur khad. The catchment area mainly comprises loose fragile shivalik hills with very little vegetative cover. The present study is carried out for swan River which originates in Himalaya Mountains. Swan River is mostly narrow and characterized by steep slopes. It produces flashy floods which inundates large tracts of cultivated land and few villages. Apart from this, State Government has allocated land to poor farmers along the banks of River swan and these farmers suffer extensive damages to their fields and properties every year due to flood in the River Swan.

3. METHODOLOGY:

Mathematical model studies were carried out to assess the adequacy of the proposed design of flood protection embankments along River swan from Babehar khad to mandwara khad for flood of 100 years return period as shown in fig 1.Based on the survey data of river, one-dimensional Mathematical Model HEC-RAS has been used to estimate the flood levels in the river Channel. The total length of river was simulated in HEC-RAS model using 54 cross sections. The discharge data used for the river was derived for 100 years return period by using empirical formula. The Manning’s roughness value of 0.035 was considered in the river reach. A return period of 100 years flood was provided by the project authorities for different river reaches, which were used as upstream boundary conditions. At downstream boundary, normal depth condition was assumed in absence of gauge-discharge data.

4. PROVING STUDY

Initially mathematical model studies were carried out without reproducing the proposed embankments. It was found that the predicted water levels for 100 years return period in different reaches were more or less in agreement with the levels used by the project authority for the design of flood embankment.

5. STUDIES WITH EMBANKMENTS

Embankments were reproduced at the end of the cross sections on the both banks of river were reproduced on the mathematical model. Simulations were carried out for the above mentioned upstream and downstream boundary conditions; water levels were computed using the described model and also velocity along the river. Maximum predicted water levels, velocities and discharge intensities of the Swan River at different reaches for the design discharge of 1318.62 cumecs.

Chainage (m)	Without embankment		With embankment	
	Water level (m)	Velocity (m/s)	Water level (m)	Velocity (m/s)
4000	502.13	1.31	502.14	1.29
3750	501.58	0.99	501.58	0.98
3500	499.84	2.49	499.84	2.47
3250	498.23	1.39	498.24	1.36
3000	496.83	2.63	496.83	2.64
2750	495.61	1.65	495.67	1.53
2500	494.09	2.5	494.06	2.34
2250	491.56	2.06	491.41	1.78
2000	490.37	3.34	489.81	3.27
1750	487.02	3.35	486.59	2.86
1500	484.8	4.25	483.89	4.23

1250	482.03	2.59	482.25	1.86
1000	480.67	3.28	480.68	3.22
750	477.51	3.66	477.53	3.28
500	474.74	3.91	474.74	3.91
250	472.87	2.52	472.98	2.1
0	470.8	3.2	470.8	3.08
-250	466.75	3.52	466.74	3.51
-500	464.18	1.42	464.18	1.42
-750	460.62	1.86	460.62	1.86
-1000	459.19	0.66	459.2	0.63
-1250	456.98	3.09	456.98	3.09
-1500	453.37	3.07	453.4	2.99
-1750	450.42	3.63	450.37	3.44
-2000	446.42	3.77	446.42	3.65
-2250	443.81	3.91	443.77	3.73
-2500	440.92	3.36	440.92	3.36
-2750	438.67	3.5	438.67	3.5
-3000	437.08	1.69	437.08	1.69
-3250	436.02	3.4	436.02	3.4
-3500	432.57	2.98	432.57	2.98
-3600	427.64	2.6	427.64	2.6

Table1.Comparision of water levels with embankment and without embankment.

6. RIVER TRAINING WORKS

Based on the different hydraulic parameters extracted from the 1-D mathematical model (HEC-RAS), the following bank protection works are designed.

1. Protection for sloping bank
2. Protection in the form of earthen embankment

It was suggested to execute the above protection works depending on the site conditions and practically at particular reach.

6.1 Design of Protection Works:

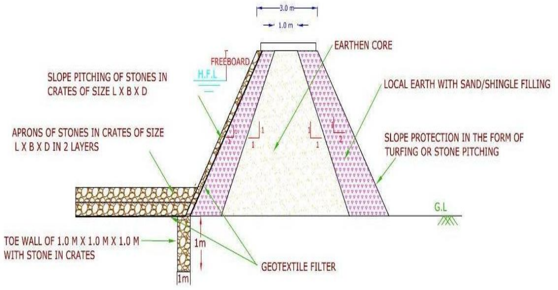

Figure 1: Typical Cross-section of Earthen Embankment

This type of protection work is suitable where the ample space for dressing the banks by filling or by excavation is possible. It should be noted that while dressing the slope by earth filling, the area inside the river banks should not be constricted beyond 10 to 15 % of the total original river width at that section. Typical computation of protection work for sloping bank is given below:

Data:

1. Velocity = 3.32 m/s
2. Bank slope (θ) = 1) 2 H:1 V (26.56^0)
3. Angle of internal friction of soil of bank material = 35^0
4. Specific gravity of stones (S_s) = 2.65
5. D50 stones being used for filling crates =175mm (for example as per specifications, the stones of size 125mm to 225mm are proposed. Therefore ,D50 is assumed as 175mm(125+225)/2)
6. Discharge intensity 'q' = 4.914 m^3/s/m (V X average MAX. depth of flow =3.32m/s x 1.48)
7. Peak discharge, Q = 112.52 m^3/s
8. d_{50} of bed material =15.23mm
9. Silt factor, f = 6.87(f=1.76$(d_{50})^{0.5}$

a) Apparent specific gravity of crates:

$G_s = S_s$ (1-Є)

Where,

S_s is specific gravity of stone and Є is void ratio

$$\varepsilon = 0.245 + \frac{0.0864}{D_{50}^{0.21}}$$

G_s = 1.85

b) Weight of crates:

$$W = \frac{0.02323 G_s V^6}{K(G_s - 1)^3} \quad , \quad K = \sqrt{1 - \left(\frac{\sin^2\theta}{\sin^2\phi}\right)}$$

Where

K = 0.62 (for bank slope of 2 H: 1V)

=0.76 (for bank slope 2.5H: 1V)

=0.83(for bank slope 3H: 1V)

W =151.147kg (for bank slope of 2 H:1V)

=123.3045kg (for bank slope 2.5H:1V)

=112.9054kg (for bank slope 3H: 1V)

C) Thickness of crate:

$T = V^2/2g\ (S_S-1)$

T = 0.3405 m say 0.4 m

Volume of crates,

V = 151.147/1850 = 0.08170 m3(2H:1V)

=123.3045/1850=0.066651m^3 (2.5H: 1V)

=112.9054/1850=0.06103m^3 (3H: 1V)

Tentatively fix crate size as

1) 0.5 m x 0.5 m x 0.4 m (0.1 m^3) (for bank slope of 2 H: 1V);

2)0.45 m x 0.45m x 0.4 m (20.18 m^3) (for bank slope of 2.5 H: 1V);

3)0.42 m x 0.42m x 0.4 m (20.18 m^3) (for bank slope of 3H: 1V)

c) Check for thickness:

Velocity head = $h_v = V^2/2g$=0.5617m

Thickness required against negative head:

$T = h_v/\ (Ss-1)$ = 0.3408 m < 0.4 m

Thickness of crate, i.e. 0.4 m is almost equal to the thickness required against negative head. Therefore, sizes of crates mentioned above for respective bank slopes are adequate

d) Launching Apron (Typical):

Scour depth below HFL, $D_L = 0.473\ (Q/f)^{1/3}$ considering maximum discharge

= 1.2010 m below HFL

Scour depth below HFL, $D_L = 1.35\ (q^2/f)^{1/3}$ maximum discharge intensity q = 4.194 m^3/s/m

= 1.84 m below HFL.

Therefore considering the maximum values from both the above cases,

Scour depth D_L = 1.85m below HFL is considered for designing the launching apron

Maximum scour depth below HFL due to bend, etc., $D_{L\ max} = 1.5\ D_L$ i.e., 2.775m below HFL

Depth of scour below Low Water Level (LWL) = 2.775 – 1.48 = 1.295m (Average of HFL-LWL = 7.6 m)

Quantity of stone/m for apron = √5 x depth of scour x thickness of pitching (0.4 m)

= 6.058865 m^3/m

Width of apron = 1.5 x Depth of scour = 1.5x1.84m=2.77 m

Thickness of apron = quantity of stone per m of apron/width of apron

= 6.058865/2.77

=2.187316 m say 2.5m

Weight of crates for horizontal bed:

$$W = \frac{0.02323 G_s V^6}{(G_s - 1)^3}$$

Hence,

W = 93.71145kg

Volume of crates = 93.71145/1850 = 0.050655 m^3 say 0.1 m^3

Hence, provide launching apron of size 0.2m x 0.2 m x 1.25m min two layers (0.1 m^3)

The above illustration is just an example.

The sloping bank protection work most suitable for controlling soil erosion and landslips, improving stability of side slopes and arresting bed load in boulder bedded hilly terrain. This type of protection work is suitable where the ample space for dressing the banks by filling or by excavation is possible. The computation of protection work for sloping bank 3H: 1V is done as per IS Code 14262:1995. The sloping bank protection works are calculated for critical velocities as shown in Table 2.

6.2. Protection in the Form of Earthen Embankment

Most of the bank slopes of river are flatter than the 3H: 1V. So, the protection works in the form of earthen embankments are suitable for these reaches in river. The sloping bank of earthen embankments on river side needs to be protected against the high velocity using slope pitching, toe wall and launching apron. The earthen embankment protection works are calculated for critical velocities as shown in Table 3.

7. CONCLUSIONS

One-dimensional mathematical model HEC-RAS was used to estimate the flood level in the river for discharge of 100 years return period. Based on the above studies following conclusion were made:

1. It is recommended that the top level of the embankments of river swan and tributaries may be finalized by using the maximum water levels obtained during model studies with embankments by adding sufficient free board
2. It is recommended to provide the protection of sloping bank for bank slope of 3H: 1V and

protection works in the form of earthen embankment for bank slope flatter than 3H: 1V

3. It is recommended to provide stone in crates for both sloping bank protection and earthen embankment protected against high velocities
4. The top width of the embankment may be kept as 3.0 m.
5. It is recommended to align the embankments such that the meanders of the river are within the embankments and the width covers the thalweg of the river.
6. To avoid damage to the geofabric filter during placement of stones in crates, a 15 cm thick layer of coarse sand or gravel should be provided over the geofabric filter.
7. It is suggested to remove the large sized of boulder from the centre of the river and the same could be used for bank protection works.
8. The stone crates may have to be filled up with different sizes of stones so that maximum density is achieved and crates are efficient in arresting the high velocity flow approaching the embankment.
10. The bank protection works (excluding launching apron) suggested shall not encroach the original river width more than 15%.
11. The restoration and maintenance of existing protection works are needed to avoid further damage to the banks.

ACKNOWLEDGEMENT

We wish to express our deep sense of gratitude to Dr. Narendra S. Chaudhari, Director, VNIT and Mr. Govindan, Director, CWPRS for constant encouragement and valuable suggestions.

Notation List

RD = River distance (Km)
RS = River station
LWL = Lowest water level (m)
HFL = Highest flood level (m)
W = Weight of the stone/boulder in (Kg)
V = Velocity at bank (m/s)
T = Thickness of protection layer (m)
g = Acceleration due to gravity (m/s^2)
Q = Discharge in (m^3/sec)
q = Discharge intensity in (m^3/s/m)
f = Silt factor
d = Mean diameter of river bed material (mm)

REFFERENCES

[1] Subashisa Dutta, Hemanta Medhi, Tapas Karmaker, Yogesh Singh, 2010, "Probabilistic Flood. Hazard Mapping For Embankment Breaching" ISH Journal of Hydraulic Engineering.

[2] Istvan Bogárdi and Edina Balogh “Floodway System Operation along Levee-Protected Rivers" ASCE Journal.

[3] Yin-Lung Chang1, Te-Yung Hsieh2, Chien-Hua Chen and Jinn-Chuang Yang "Two-Dimensional Numerical Investigation for Short- and Long-Term Effects of Spur Dikes on Weighted Usable Area of Rhinogobius candidianus (Goby)" ASCE Journal

[4] R. R. Radspinner, A.M.ASCE; P. Diplas, M.ASCE; Anne F. Lightbody, Aff.ASCE; and F. Sotiropoulos, M.ASCE "River Training and Ecological Enhancement Potential Using In-Stream Structures" \ ASCE Journal

[5] Manali A Patil and Ankit A Patil "Study Of Flood Protection Work On Men River At Tilakwad Village Of Narmada District , Gujarat". Indian Journal Of Applied Research, Vol.3, Issue

[6] B. Raghuram Singh, M.N Singh "Comparison Of Physical And Computational Model In Prediction Of Water Level In Alluvial Rivers". Journal Of The Instrument Society Of India Vol.40, No 1.

[7] Bank Protection Rivers And Lochs - Scottish Environment Protection agency (SEPA)

[8] Majumder S. K., “Protection Of Flood Embankments By Spurs With Reference to Kosi River"

[9] Patricia Freire Chagas, Silvia Helena Santos, Carla Freitas Andrade "Application of Mathematical Modeling to Study Flood Wave Behavior in Natural Rivers as Function of Hydraulic and Hydrological Parameters of the Basin," Hydrology Days 2010 PP 114-120.

[10] "Compendium of Guidelines" 2004, PP 5-11.

[11] Text Book of River Mechanics - Pierre Y. Julien

[12] http://www.hec.usace.army.mil/software/hec-ras/.