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Comparison of River Bank Stabilization Methods using Computer Simulations (Case Study: Mashalak River)

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ABSTRACT

Protection and stabilization river bank operations along the river to prevent erosion, landslides coast, demolition of existing facilities and the riverside villages is very essential to the recovery of agricultural lands. In this paper, various methods of river bank stabilization such as Levee, Groin (Epi), Submerged Vane, biotechnical revetment, Riprap revetment and concrete revetment has been investigated. To achieve this end reach Mashalak River (approximate length of 2 kilometers) were considered because of urban and is important as the study area. Using software HEC-RAS, the model was simulated with the coastal protection structures and flow hydraulic conditions were compared with existing of river. Hydraulic parameters that were evaluated are mean flow velocity, shear stress and Chanel power. To investigate the best way of training among the existing methods, the parameter of the shear stress was chosen for comparison. Finally, the epi-levee option is introduced as the preferred method of hydraulically between the methods in the selected reach.

KEYWORD

Banks Protection, Groins, Levees, Submerged vanes, HEC-RAS

INTRODUCTION

The river bank erosion can be a large source of sediment due to the influence on rivers characteristics was important in floodplain development and water resources management. Also river bank erosion caused abundant damages to in- shore land and structures [1]. So rivers bank protection and stabilization one of the most important problems that should be considered. In the selection of bank protection method, effective factors are: 1- investigate the stability of the river and select the direction and appropriate hydraulic geometry,2- identify river and study the hydraulic characteristics of the sediment and discharge regime, 3- investigate factors and bank destruction mechanism, 4- materials and specialized and technical facilities in the region, 5- economic evaluation of options [2].

Two method of bank stabilization are: direct and indirect method. Structure of stabilizing in direct method (create a longitudinal structures), directly on bank surface has located. In this research, Mashalak River due to frequent flooding problem and bed and bank erosion has been studied. Basin of this river is located between latitude 36° 38′ 20″ north and longitude 51° 33′ 0″ east and from the viewpoint of political divisions located in Mazandaran province. This basin bounded to the east by Kheyrood basin, from the west by gherdook spring basin, from the south by chehelkooh, lilisara and sanghereh height and from the north by mazandaran sea. From climate point of view, this area was the section of humid temperate areas [3]. Training methods that be investigated in this river are:1) Levee, 2) Epi (Groin), 3) Submerged Vanes, 4) biotechnical revetment, 5) Riprap revetment and 6) concrete revetment. Each of these methods briefly is presented in the following:

1) Levee is short embankment that is constructed in various distances from two sides of river bank and along the shore as artificial banks protects the lands around the river from floods during the flood that river goes out of its natural bank [4]. Usually levee is located in two sides of river waterway but if topography so that a bank pre-long, must levee is only the other side. Normal and natural flow with the construction of levee is limited to mainstream and flood flow is confined between levees. If levees are located in suitable distance from river and many barriers were not between them, for flood control would be a good way [5]. 2) epis perpendicular to the bank or at an angle toward it, from bank into the river inside be created and located at a certain distance from each other and with diversion of water flow from bank and redirect it

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towards river axis caused protection of that. Epis usually have a trapezoidal cross- section and were made from stone, gabion, earth material and river material and etc or a combination of different materials [6]. 3) Submerged vanes are small structures of leading of flow that are designed to modify the flow pattern near the bed. These vanes are mounted in groups and by changing the flow pattern near the bed caused transport of sediment in the channel cross section and thus changing the cross section of the river bed are morphologically [7]. The thickness of these vanes is 0.05 to 0.2 and these vanes are made of wood, concrete and steel [8]. Since these vanes are laid by hand and banks do not lose their normal state so aren't damaging the natural [9]. 4) Plants tree particularly willow and spruce protects river banks, planting them in river at the distance of 15 to 30 m from the river to minimize coastal erosion. Steep sides should be appropriate the use of biotechnical revetment. On cohesive banks for easier planting, maintenance and use of machinery minimum slope is 1 vertical: 2 horizontal and possibly 1 vertical: 3 horizontal [10]. 5) One of the most effective methods for making of revetments is use of concrete. Concrete as revetment on bed and banks as well as strength and good durability in chemical and different environmental conditions remained stable and gives the path regular geometric shape. Two types of concrete revetment are precast and in situ. In situ revetment mostly was executed on the surface as monolithic and slab-like but precast revetment is used as block and monolithic [11]. 6) Riprap revetment is the layer of stone without mortar, as dumped, hand-placed and or with mortar that was used for preventing of scour, erosion and water logging of river bank. Riprap revetment can be divided into several types, the most important of these are: dumped riprap revetment, hand-placed riprap revetment, hand-placed with mortar and windrow revetment [12]. In this study various options of river training have been compared in terms of hydraulic parameters. The total shear stress parameter is considered as a determining parameter. This is very important because of the role of this parameter in the erosion and degradation of river banks. In a study, function training structures implemented in a range of Ghezel Ozan River as epis and levees in the left and right bank, technical and hydraulic evaluated. Training project impact on river hydraulic and district of plan reviewed. The results showed that the hydraulic parameters such as average velocity, channel power and total shear stress by executing training project, especially in the construct area of structures have increased [13]. In another research, performance of engineering structures used in the training of Kameh River such as epi, sea wall and bottom section and also Structures used in the sub-channels such gabion, hedge, earthen and concrete barrier for reducing erosion and sedimentation of area examined. Results indicate success in stabilization operations, organize river sides and reduce rising erosion and reduce flooding in the river [14].

2)

MATERIALS AND METHODS

The small river basin and its time concentration is too low, therefore, rainfall intensity with various return periods and time durable is needed for estimating flood. No statistics were Mashalak river discharge so statistics of this river were estimated and completed with statistics and data of surrounding rivers and Physiographic parameters. The annual volume of flow was about to 32 million cubic meters. To estimate the maximum instantaneous flood of Lavyjrood Strait Station information which is consistent with Mashalak basin and has 35 years statistic is used. To calculate the peak instantaneous discharge with different return periods adjusted for the maximum instantaneous and daily discharge of Lavyjrood river with Gumbel, Log Pearson Type III, Pearson Type III, three-parameter log-normal and two-parameter log normal distribution were studied and Finally, taking into account the standard error, Pearson Type III distribution was chosen [3].

In this research for the design of training structures in the HEC-RAS software, design standard criteria have been used. The following criteria are listed for each method.

Levee: Factors that should be considered in the design of levees are determining the design flood, path or along of levee, levee height, levee longitudinal slope, embankments and side slopes and crest width of levee. In this study, due to an urban area, a flood with a return period of 50 years was chosen to design. The slope of the water level in the design discharge as slope length of levee and 3 meters in height embankments were designed and Due to the availability of river materials in the construction of embankments of this material are used. Slope towards the river 1:3 until 1: 3.5 and landward slope of 1:2 to 1: 2.5 was designed and levee crest width of 3 m was chosen [4].

Epi: In this study, 30 epi on the right bank and of 28 epi on the left bank perpendicular to the flow direction are designed so type of epi was reverse. epi length less than one- fifth the river width was average of 23 m. the Distance between the epis was almost 58 meters that epi distance to length ratio of the number 2.5 is obtained. epi crest level is align the longitudinal slope of the river and decreases downstream. Epi crest level was horizontal due to arterial Mashalak River in this reach, epis were designed non- submerged. The height of the epi to pass the design flood was determined for the left and right banks averaged 3 m were considered. Rectangular cross section and crest width of epi of 3 m was chosen. With regard to fluvial materials and stone quarries near the river, the main body of the epis of river material and they were covered in riprap revetment. Based on the available parameters and limits of existing relationships for estimating scour depth at the epi head, In this regard Gill (1972) was used, which is:

$$\frac{d_2}{d_1} = 8.4\left(\frac{D}{d_1}\right)^{0.25}\left(\frac{B_1}{B_2}\right)^{\frac{6}{7}} \qquad (1)$$

where d_2 maximum erosion depth of the water level, B_1 channel width before contracting by the breakwater, d_1 flow depth, B_2 channel width after contracting by a breakwater and D is the average particle size is noteworthy that all of these parameters in terms of are meter [15].

The average depth of scour related to 4-meter epi yielded, In conclusion, considering the depth of 1 meter epi foundation for implementing a safety factor should be greater than 5 meters.

Submerged vanes: These vanes rows 10 to 30 degree angle relative to the direction of flow in the river are planted. The initial height of them between 0.2 to 0.5 times the water depth was considered in the design flow. Transverse distance between the vanes in a vane row is less than three times the height of the vanes was designed to the vane row does not produce the system single vortexes. Longitudinal distance vanes 30 times the height of the vanes and vane length of 2 times the height of the vanes have been designed [7].

Biotechnical revetment: Vegetation, creating a resistance to flow increases the roughness and thus the water level is rising. The roughness increases with increasing density and height of vegetation [16]. To investigate the effect of vegetation on river of variation of roughness coefficient parameter were used in the model and given that the coefficient of roughness for river conditions (no training) was considered moderate vegetation, on this plane roughness coefficient from cowan table including tall vegetation was considered 0.06.

Concrete revetment: Effect of concrete cover by changing the roughness parameter in HEC-RAS model was investigated. Therefore, according to the charts roughness coefficient 0.025 was designed.

Riprap revetment: Diameter and weight of the stones according to the speed of the cross sections obtained in [17]. Table (1) indicates the diameter and weight of the stones needed for riprap revetment at various reaches of Mashalak River. Manning roughness coefficient of rock covered with the changes in simulation software was used. According to various diameters of rocks and meter formula, a unique roughness coefficient for each interval was selected in the table (1) is given.

$$n = \frac{d_{90}^{\frac{1}{6}}}{26} \qquad (2)$$

Where d_{90} (per meter) diameter of rocks [18].

To evaluate the different approaches of river bank protection, five plans was defined in HEC-RAS software. These plans were as epi - levee, submerged vanes- levee, and biotechnical revetment - levee, concrete revetment - levee and riprap revetment – levee respectively. Because Levees alone is not very effective and should be used with other structures of river training, plan wasn't defined individually for levee. Each of these plans with the state of the river (no training) was compared. To estimate the Manning roughness coefficient for the current status of river according to the bed material gradation meyer formula was used, then the Chow tables also been used to ensure.

Tab.1. estimate the Manning roughness coefficient in riprap design

Manning roughness coefficient	rock weight (kg)	diameter rock (m)	From cross section	To cross section
0.034	200	500	117	121
0.032	40	300	112	117
0.037	700	800	107	112
0.032	40	300	104	107
0.034	200	500	102	104
0.032	40	300	99	102
0.037	700	800	94	99
0.032	40	300	89	94

Hydraulic parameters that were evaluated are mean flow velocity, shear stress and Chanel power. Average velocity are frequently used in river studies and generally determine the relationship between rating curve relation, the critical shear stress, calculated scour depth and design of protective structures would be beneficial. Shear stress parameter is one of the most important parameters in the study of hydraulic flow in the river is used to determine areas vulnerable to erosion. This parameter open Chanel directly related to hydraulic radius of flow and is calculated from the following equation:

$$\tau = \gamma RS \qquad (3)$$

In this connection, γ density (N/m^3), R the hydraulic radius (m), S the slope of the channel bottom and τ shear stress (N/m^2).

Chanel power parameter also is defined as the product of the shear stress of flow Velocity.

RESULTS

After training simulation options, the geometry of the model, and hydraulic boundary before (no training) was performed and the effect of the hydraulic structures and how structures in flood situations were evaluated. With the construction of these structures, the river flow path and consequently the longitudinal water surface profiles in the current situation would be different. Figures (1), (2), (3), (4) and (5) the effect of the epi structures - levee, submerged vanes- levee, biotechnical revetment - levee, concrete revetment - levee and riprap revetment - levee on water surface profile relative to the existence status (no training) show. In Figure (1) an increase water level due to limited the flow direction in reach of studies clearly be seen.

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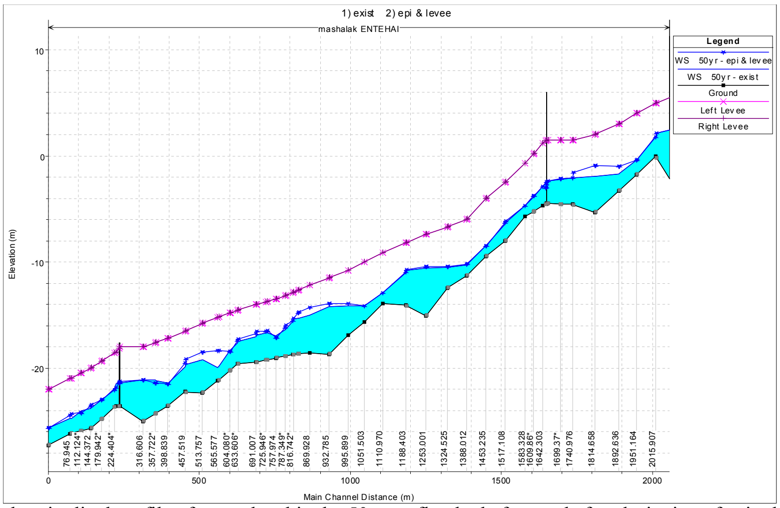

Fig.1. longitudinal profile of water level in the 50-year flood – before and after designing of epi – levee

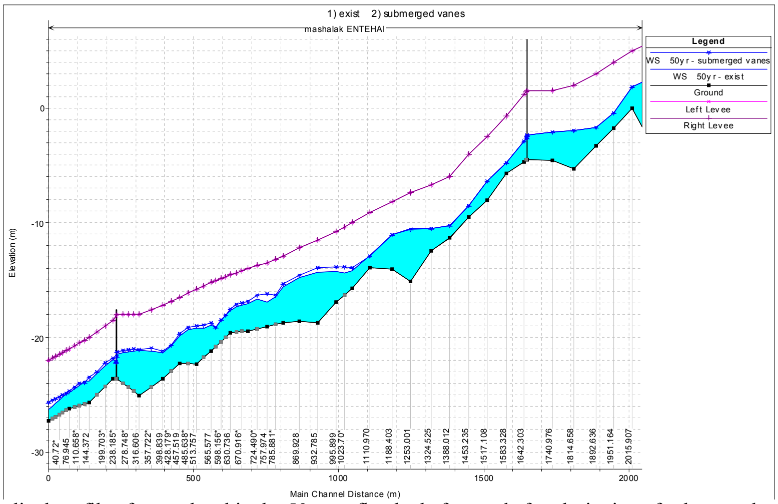

Fig.2. longitudinal profile of water level in the 50-year flood – before and after designing of submerged vanes – levee

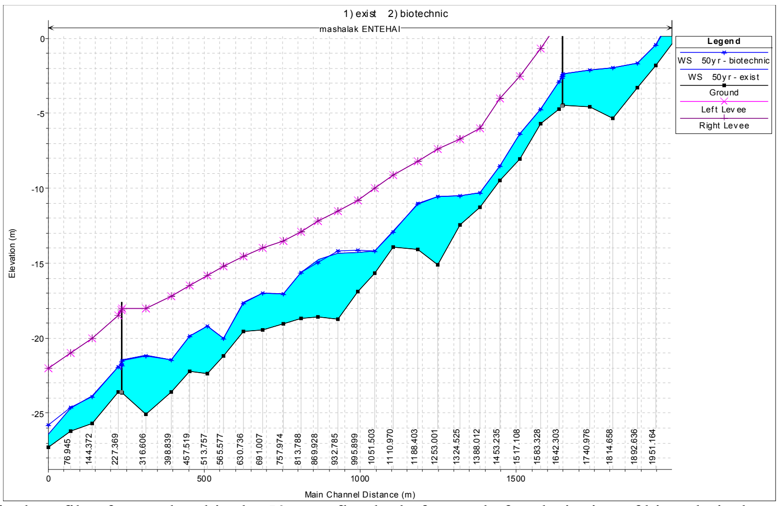

Fig.3. longitudinal profile of water level in the 50-year flood – before and after designing of biotechnical revetment – levee

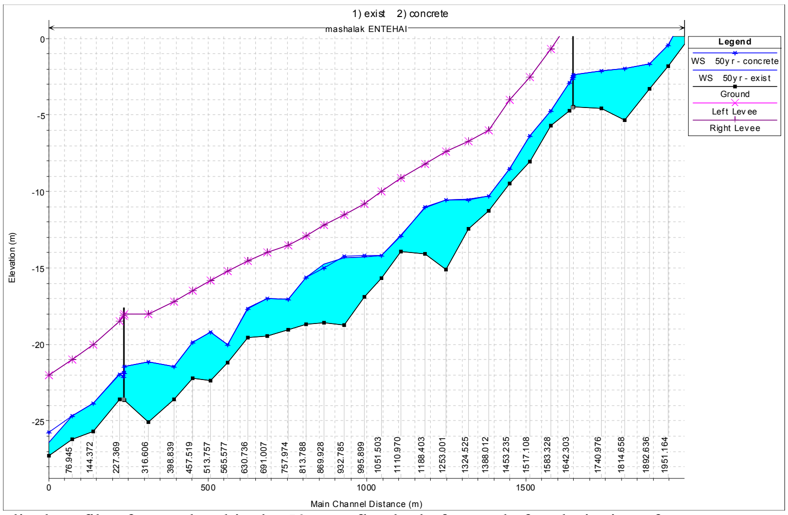

Fig.4. longitudinal profile of water level in the 50-year flood – before and after designing of concrete revetment – levee

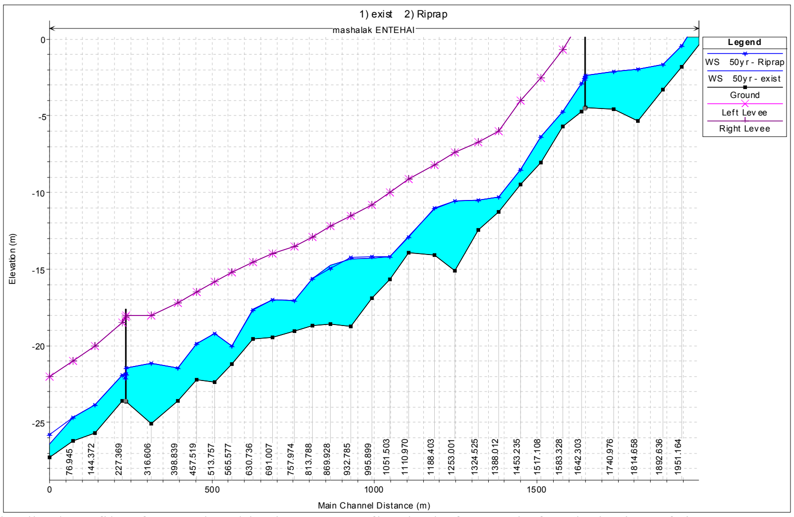

Fig.5. longitudinal profile of water level in the 50-year flood – before and after designing of riprap revetment – levee

Table 2 shows Percentage changes of hydraulic parameters such as water level, mean flow velocity, total shear stress and total channel power after designing of the structures than the current situation (no training). Reducing the size and increasing the speed are noticeable by transverse structures that the highest values are observed in the near epi structures. Also, given that the conditions to construct the structures, the hydraulic radius increases, the maximum shear stress levels increased in most sections of the breakwater is seen. Since the shear stress and the flow rate is increased by the presence of structures, it can also channel power has increased and like other parameter values are the highest in sections of the epi.
Secondary vortex flow around submerged vanes creating a change in magnitude and direction of shear stress and velocity patterns and sediment transport processes are changed accordingly. Figure (6), for example, shows the velocity distribution in the cross section station 144. 372 and also table (3) shows the velocity distribution in this cross section before and after designing of submerged vanes.

Tab.2. Percent parameters changes compared to the current state of the river

Type of structure	Total shear stress	Total channel power	Average flow velocity	Surface water level
Epi-levee	33.79	79.03	12.01	3.38
Biotechnical revetment-levee	1.61	4.74	0.95	0.10
Concrete revetment-levee	2.01	4.86	1.39	0.06
Riprap revetment-levee	2.26	4.69	1.13	0.06
Submerged vanes-levee	-4.13	-5.09	-3.55	1.16

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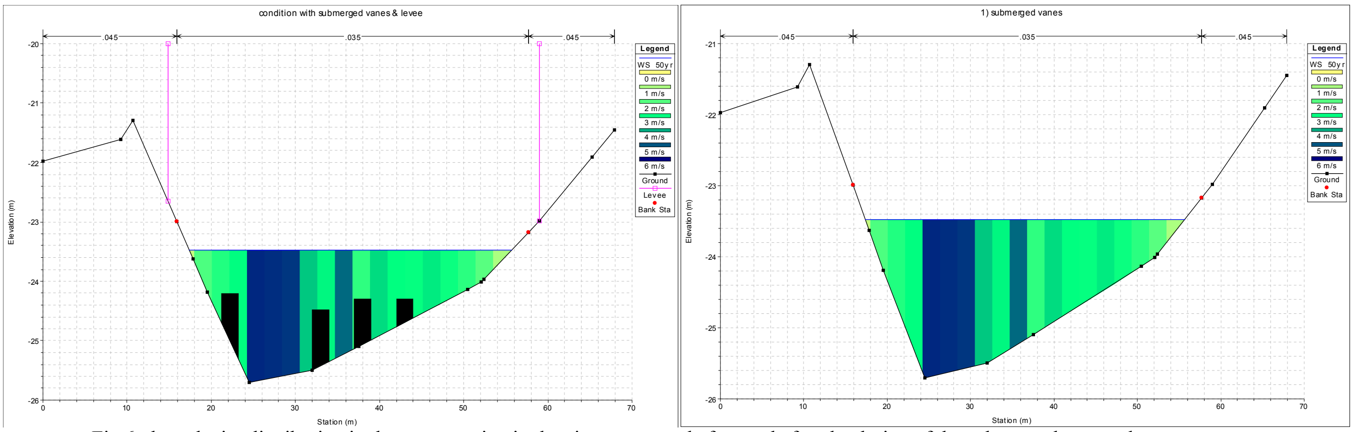

Fig.6. the velocity distribution in the cross section in the circumstances before and after the design of the submerged vanes - levee structures

Tab.3. velocity distribution in the cross section station 144. 372 before designing

Number of Sub- section	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Flow velocity (m/s)	1.5	3.2	4.6	5.4	5.3	5.2	5.1	4.8	4.5	4.2	3.9	3.5	3.1	2.7	2.3	1.8	1.1	0.2

Tab.4. velocity distribution in the cross section station 144. 372 after designing

Number of Sub- section	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Flow velocity (m/s)	0.7	2.1	2.6	3	5.5	5.5	5.4	3.6	3.1	4.8	2.5	3.4	3	3	3.2	2.9	2.5	2	1	1

Momentum and kinetic energy also fitted with submerged vanes of the flow and energy weighting coefficients (α) and momentum (β) is significantly reduced. In this study, the percent reduction of α and β are equal to 0.56 and 0.17, respectively.

To investigate the best way of training among the existing methods, the parameters of the shear stress was chosen for comparison. Because the shear stress has a significant role in determining the possible erosion of the river, the hydraulic parameters were chosen to compare. Also, compared to the same conditions and as the submerged vanes only to cross Station 1051.503 was designed to organize all the methods were compared to stations. Among these methods, the results showed that the epi - levee of the river has increased shear stress is thus selected as the preferred option.

Conclusion

Whereas the protection of the river banks is a good model to follow, flood Privacy and bed of river, especially with the use of longitudinal and coastal structures such as levees or embankments parallel to the direction of flow, will be stabilize. The finding of this research with Hosseini (1387) and Mohammadi gholrang (1385) is consistent. Submerged vanes haven't great impact on the water level and only minimal upstream level increases. Comparison between different options of bank stabilization in terms of total shear stress epi - levee method was determined as the optimal method. However, other parameters such as riverside land value and land use, environmental factors, material in the and above all economic conditions also are effective in determining the preferred option that have not been investigated in this study.

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