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Changes in hydraulic parameters in canals with sides lining

A M Arifjanov, A M Fatxulloyev, K T Rakhimov, M Y Otakhonov and D Sh Allayorov*

Faculty of Hydromelioration, National Research University "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers", st. Kori Niyazov 39, Tashkent, Uzbekistan

*E-mail: allayorov.2017@mail.ru

Abstract. Today, as a result of deformation and filtration in the channel, the hydraulic efficiency and operational reliability of irrigation networks in our Republic is decreasing, as a result, the efficiency of irrigation networks is 0.63 percent. In order to provide agricultural producers with the required amount of water on time, systematic work is being carried out to increase the efficiency of irrigation networks on the basis of several state programs. Concreting the channel can be an effective solution to these problems, but the economic costs involved are causing delays in the implementation of the works. When reconstructing irrigation canals, choosing a concreting scheme taking into account the deformation and type of filtration can be a solution to the problem. Under conditions of limited filtration, concreting both sides of canal leads to economic and hydraulic efficiency. However, there is a problem to connect the roughness coefficients of natural soil and concrete in the hydraulic calculation of canals. The article presents result of the research conducted in the 4th section of the Big Fergana Canal, according to the results, n=0.0195 in the two-sided concreted (PK-2010+85) part, and n=0.022 in the earthen part (PK-2020+85). When the channel was modeled in HEC-RAS 5.0.1 based on the hydraulic elements of the channel in PK-2010+85, the roughness coefficient of the canal was n=0.0199.

1. Introduction

Deformation processes in irrigation canals, development of algae in the channel, and operational mode and conditions lead to a significant decrease in water carrying capacity [1,2,3]. In recent years, the change in the mode of use of canals, that is, the use of main canals throughout the year, reduces the possibilities of carrying out planned repair and restoration works [4,5]. As a result, problems such as increasing amount of deformation in the canals, the development of algae in the canals have a negative effect on the reliable operation of the canals, and lead to a decrease in the water carrying capacity. About 75 percent of the irrigation networks used in our country are earthen canals, and due to the low hydraulic efficiency and operational reliability of these canals, the efficiency of the network with a total length of 190 thousand km is 63 percent [6,7].

In order to prevent the above problems, State programs for the reconstruction of irrigation networks have been developed in our country, and the works of covering the earth canal with concrete are being carried out rapidly [8]. In order to ensuring the static and dynamic stability of irrigation canals, and also increasing the efficiency of the canal, covering the canals with concrete coatings is highly effective [9,10]. However, the high cost of concreting creates problems in the implementation of this process. Therefore, the justification of the type of concreting, taking into account the following two parameters,

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allows to reduce economic costs during the reconstruction of canal, and improving of hydraulic efficiency [11,12]:

- evaluation of the deformation of the canal (erosion, deposition) in relation to the design parameters;
- substantiation of the type of filtration (limited, unlimited).

In conditions of unlimited filtration, it is recommended to completely concrete the canal which exploitation reliability has decreased as a result of the deformation [13,14,15]. However, under the conditions of limited filtration, two-sided concreting rather than full concreting of the channel bed with a strong deformation of the bed leads to a reduction in reconstruction costs and an increase in hydraulic efficiency in the use of the structure [16,17,18].

1.1. Problem setting

Today, large-scale reforms are being carried out in the field in order to improve the efficiency of irrigation networks in our Republic. In particular, a number of irrigation networks are in need of reconstruction due to high amount of filtration or strong deformation of the channel [6]. In channels prone to deformation, in cases where amount of filtration from the side is low, it is recommended to concrete only the side walls of the canals in order to reduce the costs of reconstruction. The issues of determining the roughness coefficient of canals with sides lining have not been fully studied and recommendations have not been developed. This situation causes complications in hydraulic calculations. That is, the value of roughness (n) of the channel varies in a very large range (0.012-0.035) for concrete-lined and natural earth canal, it leads to very large errors in hydraulic calculations since this value is inversely proportional to the flow rate [19,20,21].

2. Methods

A study was conducted in order to evaluate the hydraulic processes in earthen canal and canal two sides lining. The research was carried out under the following conditions:

- constant discharge in the studied section, i.s. steady flow;

$$Q = const$$

- the slope of the channel in the research reach is unchanged;

$$S = const$$

- the technical condition of the canal in the sections should be good, that is, there is no development of various algae that cause local hydraulic resistance in the canal, and there is no dampness effect caused by the turn of the canal line at different angles;
- flow cross-section elements in the sections should be similar in the following geometric aspects;

$$\frac{B_1}{B_2} \approx 1.0; \quad \frac{m_1}{m_2} \approx 1.0$$

where: B_1, B_2 = top width of canal sections; m_1, m_2 = side slope of canal sections.

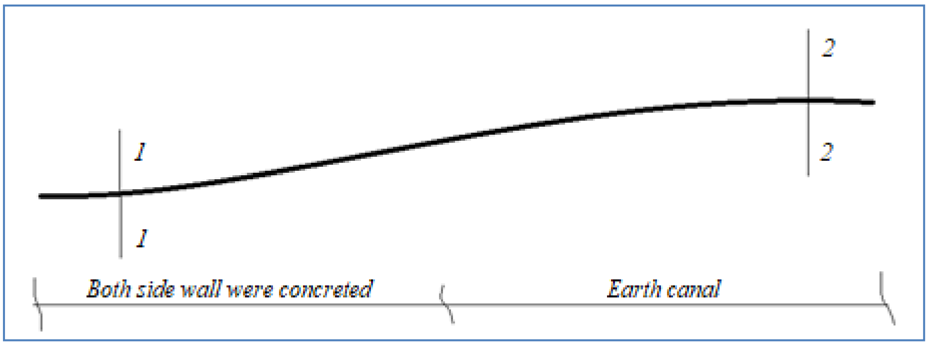


Figure 1. Line diagram of the selected research object

On the basis of these conditions, the roughness of the canal is determined based on Shezi-Manning's equations [17,18].

$$v = C\sqrt{R_h S} \tag{1}$$

where: v = flow velocity; C = Chezy's coefficient; R_h = hydraulic radius; S = canal slope.

$$n = \frac{1}{v} {R_h}^{2/3}\sqrt{S} \tag{2}$$

where: n = roughness coefficient.

From a technical point of view, to ensure the accuracy of research results, a reliable and high-precision Acoustic Doppler Profiler system (ADP), specially designed to measure hydraulic and hydrological parameters in three-dimensional flows water and based on the moving boat method for measuring the flow hydraulic elements like water discharge (Q), flow velocity (v), flow area (ω), watted perimetr (P) in the studied section, is recommended to use (Fig. 2).

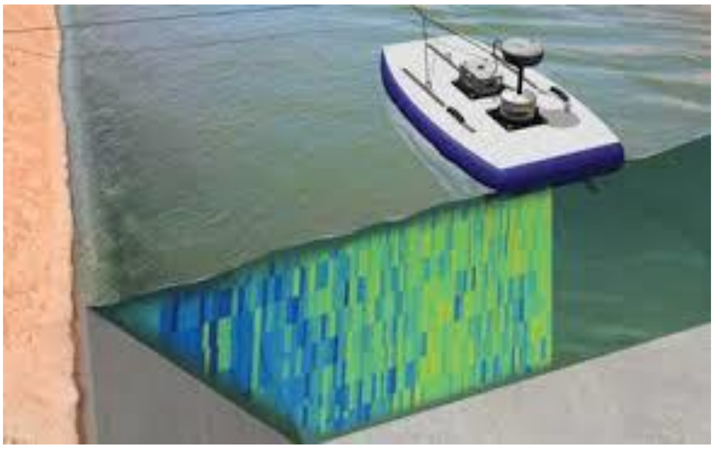


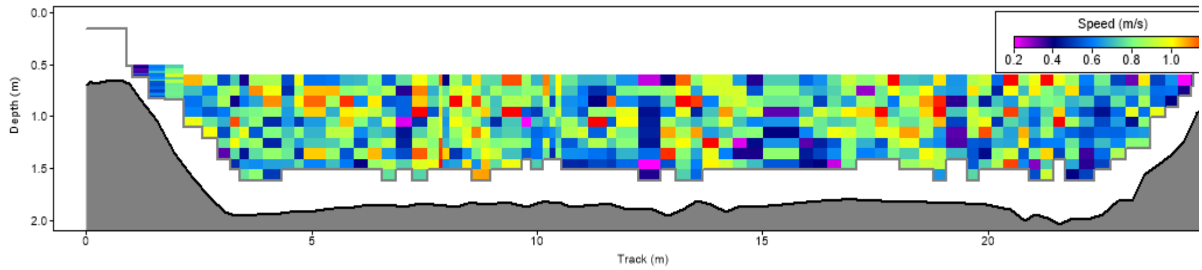
Figure 2. Doppler RiverSurveyor S5&M9

To check the reliability of the research results, that is, to determine the hydraulic parameters of canal which both sides were concreted, the simulation function of the steady flow of modeling program (HEC-RAS 5) can be used [22,23].

3. Results and discussion

Natural field studies were carried out in the 4th section of the Big Fergana main canal, PK-2010+85, which is concreted both sides, and PK-2020+85, which is made of natural soil.

a) PK-2010+85



b) PK-2020+85

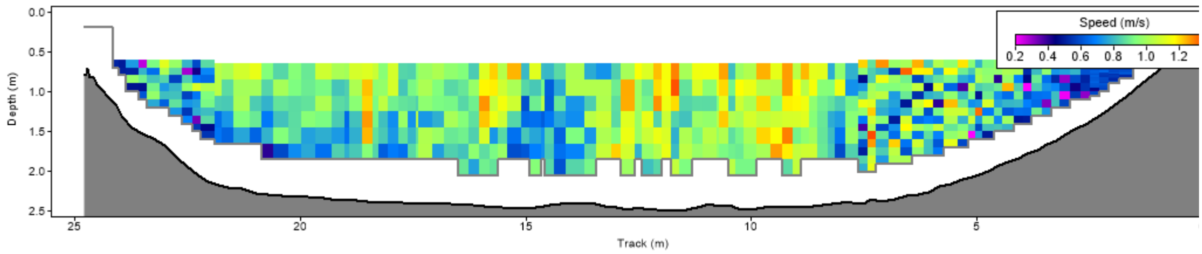


Figure 3. Results of Doppler River Surveyor S5&M9

Based on the flow hydraulic elements determined by the RiverSurveyor S5&M9 doppler, using second equations, the values of the roughness coefficient for two-sided concreted (PK-2010+85) and earth (PK-2020+85) channels were determined (Table 1).

Table 1. Hydraulic parameters of research objects and calculation results

Research object	Big Fergana main canal	
Sections	PK-2010+85	PK-2020+85
Type of canal	Canal with sides lining	Earth canal
Water discharge ($m^3 \cdot s^{-1}$)	26.498	26.412
Canal slope	0.0001	0.0001
Ratio of $\frac{B_1}{B_2}$	0.96	
Ratio of $\frac{m_1}{m_2}$	0.90	
Flow velocity ($m \cdot s^{-1}$)	0.68	0.56
Hydraulic radius (m)	1.636	1.245
Roughness coefficient	0.0195	0.022
Difference between roughness coefficients (%)	13	

In order to check the accuracy of the research work, the hydraulic elements of the flow in the section of the Big Fergana main canal (PK-2010+85), where both sides were concreted, were determined in the combination of different roughness by using the HEC-RAS 5.0.1, which is widely used for modeling hydraulic processes in natural rivers and irrigation canals (Fig. 4).

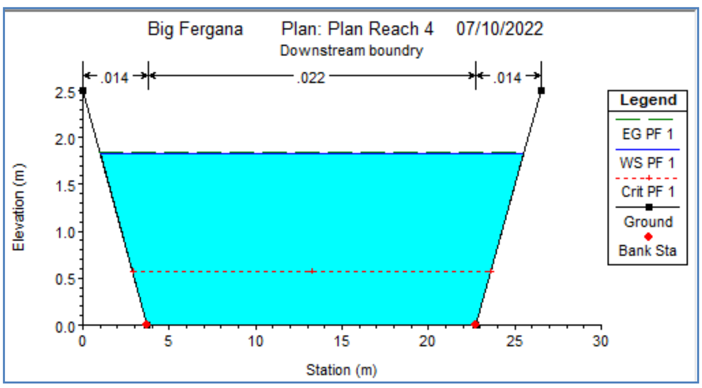
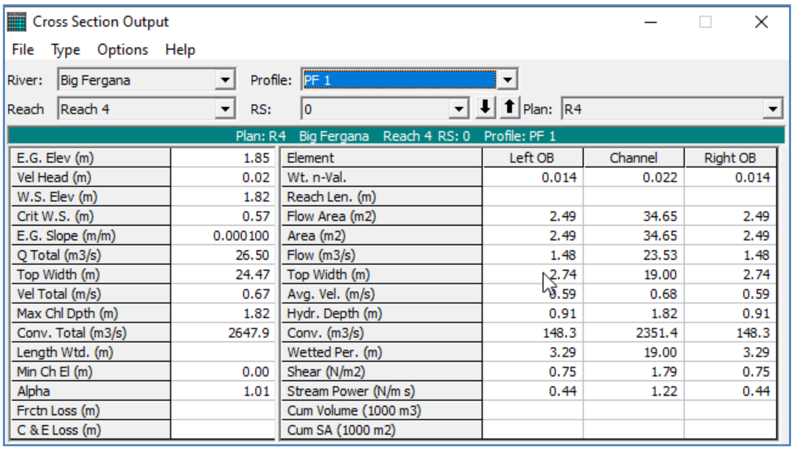


Figure 4. Cross section of flow in HEC-RAS 5.0.1

According to the results of the model, the calculated roughness of the two-sided concreted canal section was n=0.0199.


Cross Section Output

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River: Big Fergana Profile: PF 1

Reach: Reach 4 RS: 0 Plan: R4

Plan: R4 Big Fergana Reach 4 RS: 0 Profile: PF 1

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	1.85	Wt. n-Val.	0.014	0.022	0.014
Vel Head (m)	0.02	Reach Len. (m)			
W.S. Elev (m)	1.82	Flow Area (m2)	2.49	34.65	2.49
Crit W.S. (m)	0.57	Area (m2)	2.49	34.65	2.49
E.G. Slope (m/m)	0.000100	Flow (m3/s)	1.48	23.53	1.48
Q Total (m3/s)	26.50	Top Width (m)	2.74	19.00	2.74
Top Width (m)	24.47	Avg. Vel. (m/s)	0.59	0.68	0.59
Vel Total (m/s)	0.67	Hydr. Depth (m)	0.91	1.82	0.91
Max Chl Dpth (m)	1.82	Conv. (m3/s)	148.3	2351.4	148.3
Conv. Total (m3/s)	2647.9	Wetted Per. (m)	3.29	19.00	3.29
Length Wtd. (m)		Shear (N/m2)	0.75	1.79	0.75
Min Ch El (m)	0.00	Stream Power (N/m s)	0.44	1.22	0.44
Alpha	1.01	Cum Volume (1000 m3)			
Frctn Loss (m)		Cum SA (1000 m2)			
C & E Loss (m)					

Figure 5. Flow hydraulic elements in PK-2010+85 (result of model)

According to the analysis of the results, there is a difference between the values determined based on natural field studies (n=0.0195) and the values determined based on the model (n=0.0199) (Fig. 6). That is, in the natural state, the roughness of the channel is relatively small, the reason for this is the smoothing of the surface of the channel as a result of the sedimentation of small fractional on the surface of the channel.

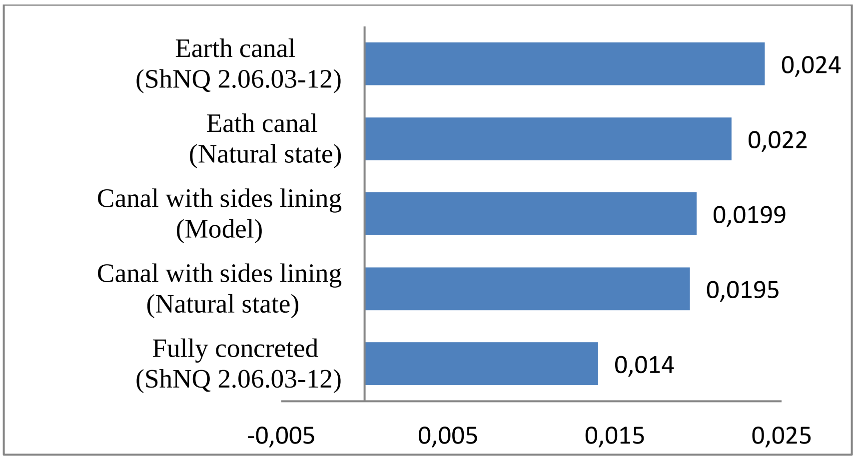

Figure 6. Change of roughness coefficient

4. Conclusion

In the reconstruction of main canals, taking into account the amount of deformation and filtration in the canal, the choice of a two-sided concreting type allows to reduce the economic costs by several times, as well as to create the best hydraulic section. The use of programs such as HEC-RAS 5.0.1 in hydraulic calculation allows to evaluate the natural process that takes place during the exploitation period. According to practical calculations, a 10 percent change in the roughness coefficient of the canal causes a 10-20 percent change in the water carrying capacity of the structure. Therefore, the correct determination of the value of the combined roughness in two-sided concreting canals makes it possible to correctly estimate the water carrying capacity of the structure, thereby optimizing the hydraulic elements of the channel like width and depth (b, h).

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