COMPARISON OF OBSERVED WITH THEORETICAL ROUGHNESS CO-EFFICIENT UNDER LINED AND UNLINED WATERCOURSES

Shamim Ara Memon*, Rajesh Kumar Soothar*, Munir Ahmed Mangrio*, Raza Hassan Saraz, Mahmood Leghari* and Ali Raza Shah***

*Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam.

**Postgraduate Student, Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam

Corresponding Author: Rajesh Kumar Soothar, Email: rk_engr195@yahoo.com

ABSTRACT: *Manning's roughness co-coefficient was evaluated for three watercourses, two lined and one in unlined condition. The values of roughness coefficient were observed as, 0.016, 0.021 and 0.035 with difference in percent of 6.67 %, 16.67% and 6.06% under concrete lined, bricks lined and unlined watercourses respectively. The observed values of roughness coefficient are slightly higher than the values reported in literature. The variations in the roughness coefficient depend on the maintenance of watercourse. The results of this study will be utilized on various watercourse conditions for the proper designing of watercourses under the prevailing condition of Pakistan.*

Key words: Lined watercourse, unlined watercourse, roughness co-coefficient

INTRODUCTION

Pakistan possesses one of the world's largest continuous irrigation system which is ranked 5th in world and 3rd in Asia and is known as Indus basin Irrigation system (IBIS) [1]. With increasing population and rapid urbanization the country is facing the worst ever crises of water shortage since many years [2]. In 1951 the per capita water availability was over 5000 m^3, this has currently decreased to 1200 m^3 and is projected to decrease to 800 m^3 by the year 2025 [3,4, 5]. Indus basin irrigation system consists of 3 large dams/ reservoirs, 19 barrages / head works, 12 link canals, 2 major siphon, 45 main canals, about 64489 km canals and distributaries carry water to 140,627 watercourses [6]. The watercourse is the convey irrigation water from miner distributary or tubewell to the field. Despite having this well established irrigation system; large amount of water is lost in conveyance system creating water logging and salinity problem in our agriculture. According to some estimation these losses are 15 % in main canal, 8 % in distributaries and 30 % in watercourses [7], which indicates that losses in watercourses are relatively greater than the losses from larger conveyance canals. The watercourse plays an important role in the development of irrigated agriculture. It provides a medium for irrigation water from channel or tube wells to fields. The proper design and maintenance of the watercourses greatly minimize theses losses and save the water. It has always been a problem for the hydraulic engineer to obtain reasonable values for the roughness co-efficient in the design of waterway therefore the purpose of this study is to help the practicing engineer to obtain a roughness value without complicated procedure.

The design parameters for the watercourse are cross-sectional area, wetted perimeter, bed slope and side slope but surface roughness plays an important role in the watercourse designing. The surface roughness coefficient using Manning's equation is a function of channel or watercourse materials, which is termed as Manning's roughness coefficient. This coefficient is derived for various type and conditions of the watercourse and is used for design of watercourse. However, for specific conditions, efforts should be made to determine this coefficient in the field for reliable design. While applying the Manning's formula the greatest difficulty lies in selection of the roughness co-efficient since there is no exact method of selecting the n value. At the time of watercourse design, to select a value of roughness co-efficient 'n' and actually means to estimate the resistance to flow in a given channel or watercourse. In this paper, to evaluate Manning's roughness coefficient value of different types and conditions of watercourses and comparison of actual roughness coefficient value with theoretical roughness coefficient values of the similar watercourses. Hence, the practicing engineer may obtain a roughness value without complicated procedure in Pakistani prevailing condition.

MATERIALS AND METHODS

Study was carried out at Latif farm, Sindh Agriculture University Tandojam. Three different watercourses were selected to determine the roughness co-efficient, two of them were lined and one was unlined watercourse. Among two lined watercourses one was concrete lined with cement joints, having trapezoidal shape and the second was brick lined with cement mortar having rectangular shape. While the third was unlined watercourse with some growth of short grass and weeds.

Estimation of roughness co-efficient 'n'

Manning's equation was employed for estimation Manning's roughness coefficient (n), that applies to uniform flow in open channels. Most design methods assume that the roughness coefficient is constant, but it actually varies as a function of flow variables. The Manning's roughness formula is expressed as**:**

$$n = \frac{CR^{2/3}S^{1/2}}{V} \qquad \text{..............................(1)}$$

Where:

n = Manning's roughness coefficient

A = Cross sectional area of watercourse (m^2)

R = Hydraulic radius of watercourse (m)

S = Bed Slope of watercourse (m m^{-1})

Q = Discharge of water (m^3 sec^{-1})

C = 1.0 in S.I unit system

Measurement of different hydraulic characteristics of watercourses

The velocity of flow in watercourses determined by using Global flow probe, while the hydraulic parameters such as: cross-sectional area, wetted perimeter, flow depth, width of the selected watercourses were measured using steel tape, while the bed slope was measured using a dumpy level and staff rod. The cross-sectional area of the rectangular watercourse was computed according to shape of watercourse through equation 2. Similarly, the cross-sectional area of trapezoidal watercourse was intended by equation 3, while, the cross-sectional area of the unlined watercourse was calculated through equation 4. The wetted perimeter is the surface of channel bottom and sides which are in direct contact with water body. The wetted perimeter of the rectangular and trapezoidal watercourse was computed according to shape of watercourse through equations 5 and 6 respectively. While the wetted perimeter for unlined watercourse was measured by using a measuring tape. The hydraulic radius is the ratio between cross-sectional area of watercourse to the wetted perimeter of watercourse was calculated through equation 7. The bed slope of the watercourse was determined through equation 8 under all selected watercourses;

$$A = \mathrm{b \ x \ d} \qquad \text{(2)}$$

$$A = \mathrm{bd} + \mathrm{Zd}^2 \qquad \text{(3)}$$

$$A = \frac{2.Td}{3} \qquad \text{(4)}$$

$$P = \mathrm{b} + 2\mathrm{d} \qquad \text{(5)}$$

$$P = \mathrm{b} + 2\mathrm{d}\sqrt{\mathrm{Z}^2} + 1 \qquad \text{(6)}$$

$$R = \frac{A}{P} \qquad \text{(7)}$$

$$Bed\ \text{Slope} = \frac{\text{Elevation of FSL at } 1^{st} \text{ station - Elevation of FSL at last station}}{\text{Distance between } 1^{st} \text{ to last station}} \qquad \text{(8)}$$

Where
A= cross-sectional area of watercourse (m^2)
b= breath of watercourse (m)
d= depth of watercourse (m)
Z= side slope of watercourse
T= Top width of watercourse (m)
R = Hydraulic radius of watercourse (m)
P = wetted perimeter of watercourse (m)
FSL = Full supply level of watercourse

RESULTS AND DISCUSSION

Average flow velocity of watercourse

The average flow velocities of selected watercourses were measured and are presented in Table 1. The average flow velocity for concrete lined, bricks lined and unlined watercourse measure as 0.399 m sec^{-1}, 0.3984 m sec^{-1} and 0.251 m sec^{-1} respectively. This is anticipated, because irregular watercourse bed and sides provide some vegetative weeds growth from the sides and bottom of the watercourses. Also, irregular watercourses have slower water velocities as compared to lined watercourses hence roughness co-efficient opportunity time increases those results in greater water losses.

Table1. Average flow velocity of watercourses

Selected watercourse	Lining material and watercourse shape	Average flow velocity (V) m sec^{-1}
WC 1	Concrete lined	0.399
WC 2	Bricks lined with cement plaster	0.3984
WC 3	Unlined	0.251

Measurement of hydraulic parameters of selected watercourses

Hydraulic parameters of selected watercourses were measured and are presented in Table 2. The results shows that, the average cress-sectional of the concrete lined, bricks lined and unlined watercourses were 0.1837 m^2, 0.0441m^2 and 0.5255 m^2 against average wetted perimeter of 1.171 m, 1.87 m and 2.115 m respectively. This has resulted in greater wetted perimeter and cross-sectional area of watercourse. The hydraulic radius of the concrete lined and bricks lined watercourses were 1.156 m and 0.2345 m respectively. While, the average flow velocity yielded to be 0.399 m $sec^{-1}$and 0.3984 m sec^{-1} respectively. In other watercourse, the hydraulic radius of unlined watercourse was 0.2484 m and the flow velocity was occurred 0.251 m sec^{-1}. The average bed slope of the concrete lined, bricks lined and unlined Watercourses were 0.00045 m m^{-1}, 0.0005 m m^{-1} and 0.0005 m m^{-1} respectively. As expected, the bed slope is greater and flow velocity is higher in these cases. In contrast, water velocities are higher under the lined watercourses; this in turn provides lesser roughness co-efficient to occur.

Table 2. Cross-Sectional Area, Wetted Perimeter, Hydraulic Radius and Bed Slope of selected watercourses

Water course	Lining material and watercourse shape	Area 'A' (m^2)	Wetted perimeter 'p' (m)	Hydraulic radius R = A/P (m)	Bed slope 'S' (m m^{-1})
WC 1	Concrete lined	0.1837	1.171	1.156	0.00045
WC 2	Bricks lined with cement plaster	0.441	1.87	0.2345	0.0005
WC 3	Unlined	0.5255	2.115	0.2484	0.0005

Roughness co-efficient observed

The results revealed that the roughness co-efficient of selected watercourses are presented in Table 3. The roughness coefficient values of the selected watercourses were observed as, 0.016, 0.021 and 0.035 under concrete lined, bricks lined and unlined watercourses respectively. This indicates that roughness coefficient in unlined watercourse is higher than the lined watercourse which is because of the conditions and material used in the watercourses.

Table 3. Estimation of Roughness Co-efficient of the selected watercourses

Watercourse	Lining material and watercourse shape	Hydraulic radius $R^{2/3}$	Bed slope $S^{½}$	Estimated value of roughness co-efficient
WC 1	Concrete lined	0.2913	0.212	0.016
WC 2	Bricks lined with cement plaster	0.3806	0. 2236	0.021
WC 3	Unlined	0.395	0.0212	0.035

Comparison of observed value of roughness coefficient 'n' with theoretical value given by V.T Chow [8]

The results obtained by observed value of roughness coefficient 'n' and theoretical value by Manning are summarized in Table 4. The comparison between these values with theoretical values of roughness coefficient 'n' has been demonstrated in Figures 1. The difference between observed value and theoretical values of roughness coefficient 'n' were 0.001, 0.003 and 0.002 under concrete lined, brick lined and unlined watercourse respectively. As the found difference percent of 'n' is 6.67 %, 16.67% and 6.06%. Results reveal that observed roughness co-efficient values are higher than reported literature for watercourse materials. However, the variation in the roughness coefficient depends on the watercourse conditions. Hence under prevailing condition the observed values of roughness co-efficient 'n' can be used for the designing of the watercourses.

Table 4. Comparison of observed value of roughness coefficient 'n' with Manning

Watercourse	Lining material and watercourse shape	Roughness co-efficient 'n'		Difference	Difference of 'n' (%)
		Manning's 'n'	observed value 'n'		
WC 1	Concrete lined	0.012-0.015	0.016	0.001	6.67
WC 2	Bricks lined with cement plaster	0.012-0.018	0.021	0.003	16.67
WC 3	Unlined	0.022-0.033	0.035	0.002	6.06

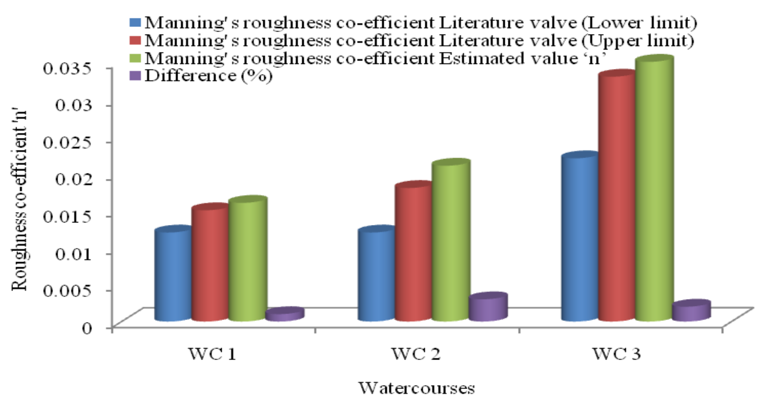

Figure 1. Comparison of observed and Manning's roughness coefficient 'n' value

CONCLUSION

The roughness coefficient values in lined as well as unlined watercourse under existing condition are slightly higher than the values given by Manning's. The roughness co-efficient can be reduced by properly maintaining the lined and unlined watercourses.

LITERATURE CITED

[1] Qureshi, A. S. 2011. "Water management in the Indus basin in Pakistan: Challenges and Opportunities". *Mt. Res. & Devel.*, **31**(3): 252-260.

[2] Starkey, M. 2012. "The Water Crisis in Third World Countries". *A Senior Thesis submitted in partial fulfillment of the requirements for graduation in the Honors Program Liberty University.*

[3] Chandio,B. A and R. Aftab. 1999. "Indus river system and its water management". *Proceedings of National Workshop on Water Resource Achievements and issues in 20th century and challenges for next millennium, Islamabad, Pakistan.*

[4] PWAPDA, 2012. "Project for USAID Assistance (Ongoing-New) for 2012-2017". *Pakistan Water and Power Development Authority*, http://www.wapda.gov.pk/pdf/proposedusaid.pdf. pp-1-47.

[5] ORSAM, 2013. “Orsam water Bulletin”. *Weekly Bulletin by ORSAM Water Research Program.* **124**: 1-107

[6] Anonymous. 2010. “Annual flood report. Ministry of Water and Power, Government of Pakistan”. http://www.ffc.gov.pk/download/flood/archieve/Annual.report2010.pdf

[7] Rajput, M. I. 2005. “Kala Bagh Dam and Sindh, a view point, Sindh Graduate Association (SGA) Karachi”

[8] Ven te chow (1959), “Determination of manning roughness co-efficient” Open channel hydraulics, *Mac Graw hill book company London*.