Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 8, S. 175-182, 11, 2024
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Araştırma Makalesi

IJANSER

https://as-proceeding.com/index.php/ijanser
ISSN:2980-0811

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 8, pp. 175-182, 11, 2024
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Research Article

Optimum Design length for Concrete Canal Section for Minimizing Costs of Seepage Losses, Lining and Earthworks

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(Received: 02 December 2024, Accepted: 06 December 2024)

(3rd International Conference on Recent Academic Studies ICRAS 2024, December 03-04, 2024)

ATIF/REFERENCE: Rehman, F., Akhtar, H., Zaheer, M., Ravzi, F. F., Ali, S. & Ullah, J. (2024). Optimum Design length for Concrete Canal Section for Minimizing Costs of Seepage Losses, Lining and Earthworks. *International Journal of Advanced Natural Sciences and Engineering Researches*, 8(11), 175-182.

Abstarct:Earth's life is based on water. It's a rare natural resource. In all its forms, i.e. surface water and g round water, the distribution of water on earth is not consistent. In many regions, groundwater quality vari es from fresh to brackish. It may not be appropriate for drinking and irrigation purposes. Surface water has high-quality fresh water and is primarily used for irrigation purposes by diverting water into canals from rivers. As this powerful and terrifying device enters the irrigation system, some water is lost. Due to less water availability and relatively large network disruptions, in the dry spell, and mostly during the winter season, there is a lack of canal water supply. The losses are much higher in the watercourses than in the main channel and distributaries. So, the face of the farmer is a severe shortage of irrigation water issues. Besides this groundwater injection, that is also that which reduces the groundwater level. The conveyance losses in watercourses can be high by applying these lining methods. To overcome this problem, it is necessary to work out the optimum lining length to ensure maximum water savings. It is very important to estimate the losses of water transport in watercourses. In the review, a detailed study was conducted to measure conveyance losses through the inflow and outflow operational approach. The losses in a comparable geographical area from both lined and unlined watercourses were measured and used to calculate the percentage of water savings. In this study, also from field measurements, huge losses during unlined watercourses and less losses in the lined watercourses have been identified. In this research work, the percentage of lining is also numerically checked and validated. The percentage of water saving and percentage increase in lining was modelled using optimum lining length for unlined water courses. The optimum percentage of lining length was estimated as 60 percent, resulting in overall economic benefits and 90 percent water savings.

Keywords. Canal, Optimum Length, Cost & Economical Ways, Food & Water Security.

I. INTRODUCTION

Water is a valuable gift of Nature. It has many usages in human life. With the increase in population, the demand for this natural resource is increasing day by day. (OFWM, 2012) In a running day the requirement of water is m0re than its supply. So, it is a dire need of time to take measures to overcome water losses increase during conveyance of water. Conveyance losses in distributaries are about 25%. Arshad et al. (2009). Comparing the average seepage loss of 43.5% from lined to the average seepage loss of 66% from earthen water courses, he found that the lining decreased seepage loss 21.5%. It has a very incremental effect on agriculture crop productivity. In our country Pakistan's large way of groundwater availability is the Indus Basin Irrigation System (IBIS), which includes of a network of reservoirs, dams, head facilities, linking channels, major rivers, distributors, watercourses and small watercourses. Loss rates vary with length of watercourse, variability of discharge, retention time, form of soil, and soil density. Sultan et al, (2014). Show that in Pakistan nearly 42.5% of the seepage loss arise in lined water courses and 66% losses in earthen water courses and in India 11% of seepage loss arise in lined water courses and 19-26% in earthen water courses. High vegetation density, sediment deposition, siltation problem, leakage, lack of maintenance, sharp curves are the main reasons for losses. (Zeb et al., 2000). Conveyance losses include both evaporation and seepage loss. The main causes of evaporation loss are high temperature, moisture and wind velocity. Essentially, evaporation losses cannot be treated, but flow losses can be managed between porous soil and channel discharge by supplying various materials such as brick lined, pcc lined, asphalt materials and geo-synthetic materials etc. In canals the major reason of water losses is the seepage loss as compared to other form of losses. Memon et al, (2013). A large amount of water is misplaced from the irrigation canal due to seepage from banks. It is found that 40% to 50% of water is lost between the canals head works to the farm gate. 40% to 50% of seepage losses reduced in lined canal, subsequently logging of water become insignificant. Increased conveyance efficiency from 69% to 91% resulting in an important rise in cropping amount. Kahlown et al, (2005) encountered different types of channels with different materials and with different geometric design perspectives. The losses in brick masonry and cement-concrete lining channels were0.46lps / m3 and 0.20lps / m3. The basic definition of total losses in the supply of channels includes losses in evaporation, seepage and service. The main reason of cracks in lining canals are low-grade quality lining materials, growth of unwanted plants, imperfections in construction and weather impacts. Seepage losses in unlined canals are 0.415m3/s, bricked lined canals are 0.0511m3/s, PCC lined canals are .0028m3/s and in PCC and LDPE film lined canals are. 00012m^3s. Lining canals are reducing the seepage loss nearly 87.68 percentage, 99.30 percentage and 99.97 percentage respectively. (Uchdadiya et al., 2014). Jadhav et al, (2019). Determine overall loss from lined, earthen most important canal sections and earthen field channels was observed as 0.184mm3, 0.61mm3 and 0.183mm3 respectively.

Bikram Saha (2015) investigated water losses in Canal and measured reduction in irrigation canal. Comparative studies of different research on different canals were done for water loss and also determine the best material for the reduction of conveyance losses. Reasons of conveyance losses were also mentioned as seepage loss, evaporation loss, operational and leakage loss. Water losses also depend on the site and environmental conditions. Lining is the universal technique to increase conveyance efficiency. Bikram Saha (2015) lining canal reduce the conveyance losses on an average 18 percent to 19 percent. Israel et al. (2015) identifies the inlet losses in the unlined channel that have been found to be greater than the lined channel losses of 82.8% in the unlined channel. We suggest that small and medium-sized farmers use the mixture of clay and bentonite with a moisture-saving capacity of 82.8 percent within the study area. The main purpose of this study is to assess the flow through an earth-lined canal to suggest the canal lining material in a selected area in Akwa Ibom State. The specific goals, however, are 1) Designing and building irrigation channels. 2) Line the channels with readily available clay earth products and some bentonite amounts.3) Measuring the depletion of the inlet in the lined channel. (4) The lining material for earth canals of the same soil type should be recommended or not. Meijer et al. (2006) investigated the impact on water availability of concrete irrigation canals. The yearly ground water restored in the irrigated zones was estimated to be minimized by nearly 50% after concrete lining. It saves a huge quantity of water that can be used to expand the irrigation area to allow more people to benefit from the available irrigation water. The FAO projects that in the selected 93 developing countries the irrigated zone will only increase by 23 percent over the period 1998-2030. However, it is expected that the successful harvested irrigated area will increase by 34% (considering the increase in crop intensity). (Khan, Gabriel, Akhtar, & Zaheer, 2024) Unlined canals have an average conveyance efficiency of 81.93%, which is much lower than that of PCC and brick canals, which are 97.75% and 93.96%, respectively. Brick lining and PCC were predicted to minimize seepage losses by 13.03% and 16.82%, respectively.

From the above discussion, it has been revealed that losses in the different types of lined canal have not been estimated in Thal canal and these losses were also not compared to unlined canal. Seepage loss is only the significant loss which occurs in the lined and unlined canals. It is, therefore, the need to study these losses in different types of lined and unlined canals. However, instead of doing the entire lining of canal, there is a need to determine the optimum lining length in canals that reduce number of losses and gives a cost efficient lining length. This degree will benefit in more availability of canal water for agriculture productivity at nominal and compete able cost. The study will provide guidelines, rules and impacts of optimum lining length of canals.

II. METHODOLOGY

Study area

The canal under consideration is located in District Mainwali, province of Punjab. The coordinates of Mainwali district are 32º.55’06.71’N, 71º.31’18.9E having an elevation of 190 m to 210 m. Most of the district lies in Thal desert region. Indus River flows through the district. The temperature ranges from 0 ˚C to 52 ˚C. Mean annual precipitation is quite less and ranges from 150mm to 200mm. The length of canal is 3362km. Cotton, wheat, sugar cane and rice are the most important crop grown of the area. Specific area of study is lined main canal and Muhajir branch (unlined).

Fig. 1

Requirements for crop water

For wheat, cotton, rice, sugarcane and fodder crops, the net crop water necessities of 0.4, 0.85, 1.8, 2.0 and 0.5 m were used. These 5 main crops cover over 82% of the whole crop area of the canal and consume 84% of the whole water required for the whole crop consumption necessity of the crop area. These include wheat (12.8% of the total), cotton (15.9% of the total), rice (28.3% of the total), cane sugar (15% of the total) and fodder (6.8% of the total). The whole water desires for Kharif crops and Rabi crops are 176 hectometers. Comparison of the requirements for crop water and available water sources showed a shortage of over 51 percent in Kharif and 54 percent in Rabi seasons.

Properties of the Canal Quantity

Remodeling of the channel segment imposes some limitation on the wide variety of different dimensions; the last de-signed section specifies several values including longitudinal slope, full supply depth and full supply depths.

The availability of water

The canal is equipped for a standard 5500 cusec discharge at the end. Cotton, sugar cane, wheat, rice, fruit and vegetables are the most important crops. The thal canal's water quality is very volatile due to the stochastic nature of the flow. The average annual availability at the channel head and farm gate is 0.187 MHM and 0.099 MHM based on 5-year channel diversion resulting in a large water loss of 0.099 MHM

The study's specific goals were:

- Assessing the effectiveness cost and lengthy-term efficiency of traditional and lower cost lines under field conditions.
- To carry out cost-benefit analysis of the lining forms tested.
- Suggest adequate linings for future field channel development.
- Effective cost since its economic return (Conserved water / investment) is greater than the order of magnitude achieved by improving the structures.

Costs of lining

Depending on the local cost of lining material and labor and the length of the channel to be lined, the cost of lining can be very high. The lining material's price varies from location to location. Irrigation committees and farmers considering lining the canals should collect information on the material prices and the labor involved in their irrigation scheme.

In flow –Outflow method.

The method of inflow-outflow to determine water losses is really favorable as the losses can be measured even during the channel's regular working condition. The channel is divided into the correct segment number based on the channel size especially length. Cross-regulators can define the borderline between two sections along a channel or branch channel. Then, it is possible to modify the entrances at each cross regulator to create a discharge rating for each flow control section along with each splitting distributary head regulator in each sector. The flow is measured at the heads of the section in the inflow-outflow process to determine any alternation in the amount of water entering the channel; water phases are monitored at sufficient intervals to ensure a stable flow situation. After these water stages are noted in a relatively short time span of one or two hours at each sectors. When steady-state flow conditions occur during the test period, the findings will be recognized; if not, the experiment will be performed again until this condition of steady-state flow is obtained. With the help of the current meter or flume, the flow rate is noticeably observed. The water flow level is kept steady during the investigation. It contains direct measurement of the water that passes into and out of the canal. The evaporation is measured using the evaporation panel and deducted from the difference after multiplying with the correct pan coefficient, but evaporation is generally ignored in the case of a channel as the surface area is very minor. Using the current meter or flume, the flow rate is actually determined. Water flow speed is kept constant throughout the experiment. This technique of inflow-outflowing is based on the principle of water balance. This includes calculating the direct flow of water in and out of the canal.

$$S = Q_{IN} + D + I + R - Qout - E.$$

Where,
S = Seepage loss

R = Direct rainfall

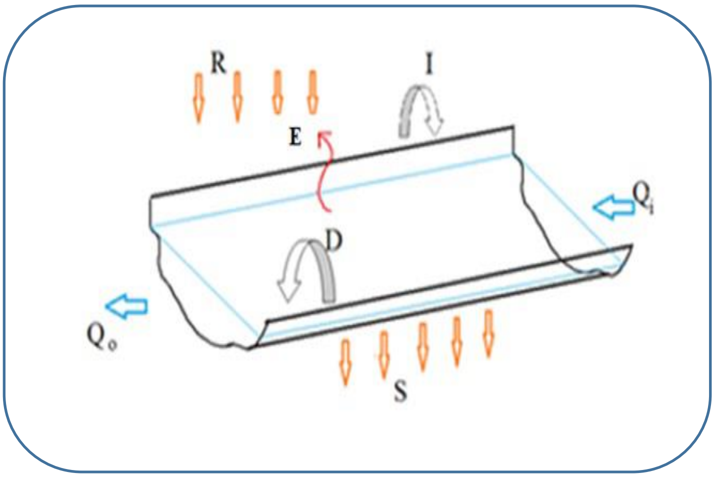
Qout = Outflow discharge

Qin = Inflow discharge

D = Flow diverted along the reach

I = Inflow alongside the reach

E = Evaporation loss.



Data and measurements.
Historical discharge data will be collected from the irrigation deportment of Punjab. Using inflow-outflow method to measure conveyance loss. The selection of canal main line lower one unlined branch which name is Dully Wala reach (from RD 00+00 to Rd 38+500) have been selected in province Punjab (Pakistan). Gauges are already installed at head and tail by Punjab irrigation department for data collection of discharge at points on daily basis. Collected data is analyzed through polynomial regression analysis. An ANN technique is applied through Two Layer Back Propagation (TLBP) for model development. The actual water saving is plotted against the predicted water saving. Variance, Bias, Mean and Root square are calculated to check model efficiency. The values of percentage water saving are taken from model against queried percentage of length. These results are plotted and compared for obtaining the optimum lining length of Canals**.**

III. FINDINGS AND DISCUSSION

It is important to compare the costs and benefits of lining before the decision is made to line a path. The flow velocity can increase due to the channel's smooth surface by lining the pipe. For example, with the same channel bed slope and the same channel size, the flow rate in a lined channel may be 1.5 to 2 times lower than in an unlined channel, indicating that the channel cross-section in the lined channel may be lower to provide the same discharge. The defined channels were located in the same geographical region, including lined and unlined channels, so all these channels could be assumed to be subject to the Specific geotechnical and hydraulic features. The losses levels were measured by the technique of inflow outflow for each channel by in-between each channel into 3 parts, head, middle and tail. Zhangi et al. (2016) studied the different methods (field experiments, empirical formula, Kostiakov formula, numerical simulations and ponding method) for measuring the seepage losses in goongan lateral canal G.L.C. (before lining and after lining) and zuoui field canal Z.F.C. (before and after lining). Seepage losses are show in table 1.1.

Table 1.1: Seepage losses in G.L.C. and Z.F.C. before and after lining by zhangi et al.(2016)

Canals	Seepage losses	
	Before lining	After lining
Gongan lateral canal	8.20L/m^2.h	4.0L/m^2.h
Zuoui field canal	12.90L/m^2.h	5.92L/m^2.h

Table1.2 Calculated using (Inflow Outflow Method) water loss per 100 m (liters / sec).

Canal	Seepage losses lps /$_{100}$ m at			Average
	Head	Mid	Tail	
PCC	1.85	1.42	1.05	1.44
Brick	2.24	1.10	1.65	1.66
Unlined	1.25	2.45	2.97	2.22

In the case of unlined canal, the highest average loss rate/100 m is equal to 2.22 was observed in canals after losses from each portion of the channel were calculated as water savings obtained by lining. Using gauging rope, the method of inflow outflow was applied and losses for both types of channels were measured. The loss difference indicates how much water saving was measured with the rate of increase in the length of the canal. Once the results have been recognized, it is suggested that any channel lining be viable up to 60 percent, which can save the maximum water loss of about 90 percent, beyond which the total savings are very low and only about 10 percent overall compared to the remaining 40 percent. It is therefore believed that the lining of the canal is carried out to a maximum level of approximately 60%. Syed et al. (2014) studied the impact of lined canal on water losses. Comparatively study of three different types of canals such as unlined canal, improved unlined canal and precast canal. Average conveyance losses in existing unlined canal, in improved unlined canal and precast canal are shown in table 1:3.

Table1:3: Average conveyance losses (%) Syed et al. (2014)

Canal	Unlined Canal	Improved unlined canal	Pre-cast canal
Mithapukur	41	18	12
Manikgonj	48	21	11
Dhamrai	45	24	13

IV. CONCLUSION

The research aims at determining the optimum canal lining length and ultimately improving conveyance capacity by saving water and making the project more feasible and cost-effective. To this end, three types of channels have been chosen under different geographical situations, including 1 for unlined channels and 2 for lined channels. Water savings are increasing quickly for regular developments in the length of unlined canal, but there is no major change in water savings after 60 percent of the lining. Consequently, the full economic gain can be achieved by using only 60% of the lining's total length, as it can save up to 90% of the water. This 90 percent water saving provides volumes of 400 to 800 acres of water (reflecting a managed average of 470 acres) that can be used to irrigate a further 94 acres of Rabi and 62 acres of Kharif crops.

ACKNOWLEDGEMENT

The author would like to thank all persons who helped them throughout the research particularly the NUST institute if civil engineering (NICE), Islamabad for support of this research.

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