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Seepage Losses Through Canals & Minors

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Abstract

Irrigation is the key factor that boosts agricultural production. Our aim is to increase agricultural production per unit volume of water, per unit area of cropped land & per unit time it is essential to see that the water available for irrigation is judiciously used and as far as possible water loss through conveyance is prevented. The main loss of water during transit is seepage loss. Main purpose of this paper is to calculate seepage losses through lined and unlined canals and lined and unlined minors. The best method for this is to measure accurately the inflow and outflow for the system. The difference between inflow and outflow will give the losses. Seepage losses depend upon the time for which the canal runs, type of soil i.e. capacity of soil to conduct water, wetted perimeter, length of channels, operation policies, method of construction and embankment material atmospheric temperature, microbial activity, type of lining, growth of aquatic weeds etc. The loss of water due to percolation seriously affects surface irrigation. "studies on seepage losses through canals and minors" was undertaken at the site of Paithan Left Bank Canal and Lassina Left Bank Canal. Maximum seepage loss was found to be 7.40 cumec/Mm2 in the second section of unlined canal and minimum seepage loss was found to be 0.80 cumec/Mm2 in first section of lined canal. Average seepage losses in lined and unlined canal were 0.836 to 7.063 cumec/Mm2 respectively. If lining is provided the seepage losses could be reduced by nearly 88.16%.

1. Introduction

Irrigation is the key factor that boosts agricultural production. In arid and semi-arid regions of India availability of water for irrigation has always been a constraint in crop production. States like Rajasthan, Karnataka, Gujarat and Maharashtra have limited water resources in comparison with other states[1]. Water is going to be a crucial limiting resource for farm production in the future especially so in the state of Maharashtra. The state has 20.26 Mha of cultivable area. Out of which 12 per cent area has been brought under irrigation [2].

It has been reported in Maharashtra Irrigation Commission's Report [3] that 52.6 and 18 lakh hectares can be brought under irrigation by rain water stored in reservoirs and wells respectively. This is about 30 per cent of the cultivable area of 20.26 Mha in the Maharashtra State.

Seepage is the downward lateral movement of water into soil or substrata from a source of supply such as reservoir or irrigation canal [1]. Seepage losses depend up on the time for which the channel runs type of soil i.e. capacity of soil to conduct water, wetted perimeter, length of channel, operation policies, and methods of construction and embankment material, atmospheric temperature, microbial activity, type of lining growth of aquatic weeds etc. The loss of water due to percolation seriously affects surface irrigation. The seriousness of such loss is keenly felt in arid and semi-arid region where the demand for water far exceeds the availability. Different research workers reported the loss and estimated that on an average seepage losses were 15 to 20 percent in conveyance. Because of excessive seepage losses there is substantial gap between irrigation potential and its utilization. Excessive seepage losses contribute to water logging of lands and salt and alkali concentration in soils. These constitute a serious economic waste and are also associated with problems of leaching of nutrients. Aeration in agricultural fields which deteriorates soil and lead to lower crop productivity. It is common observation that the major seepage losses occur in the field where the channels are not properly lined lining irrigation canals is the simplest and most effective method of saving both water and land in irrigated area. Although costly it is likely to be cheaper than developing additional water. Irrigation canals are lined for the purpose of decreasing the conveyance and seepage losses. Providing safety against branches. Preventing weed growth, retarding moss growth, decreasing the capacity to convey water. Total loss in the watercourse is taken as criterion for deciding on the lining. Importance of lining of channels has been in context overall storage of water resources. It has been estimated that due to lining the area under irrigation may be increased by 20 per cent. Prevention of seepage losses from field channels will enable the farmers to irrigate more area and to avoid severe water logging problems. In order to induce farmers to line the field channels the information about various lining material in respect of their relative effectiveness and economics is required to be made available to the farmers.

Keeping in view the practicability, the losses through lined Paithan left bank canal and lined minor under the command area of Jaikwadi, unlined Lassina Left Bank Canal and lined minor under the command area of Yeldari project was undertaken with following objectives:

1. To measure seepage losses through lined and unlined canals and minors.
2. To determine the roughness coefficient values of lined and unlined canals and minors.

2. Review of literature

The main focus of the study was to determine the seepage losses through canals. The studies on estimation and measurement of seepage losses were of much interest to the irrigation scientist. The research workers have done lot of work on the seepage aspect of the irrigation water management. The attempt has been made to review the research work done in the past in respect of evaluation and determination of seepage losses through canals. The work most pertinent to present study has been reviewed and presented in this chapter under the following head:

1. Seepage loss through canal network
2. Seepage loss through different lining materials.
3. Channel section and prefabricated concrete lining.

2.1 Seepage loss through canal network

[4] Stated that evaporation losses were lower in lined canal having smaller cross section and consequently smaller width than unlined canal. Water loss causing an actual flow decrease, was caused by seepage across wetted perimeter of the unlined canal. Bouwer et al [5] determined seepage rates in open channel with the help of salt penetration into the bottom material. A portion of the bottom was covered with crystals of non-deflocculating salt. The rate of advance of the concentration in the bottom material was measured with an electrical conductivity probe. Laboratory studies showed that seepage rate could be calculated by multiplying this salt penetration rate by the porosity of the bottom material.

Edward [6] while commenting on 'Economic problem of irrigation canals regarding seepage losses' given by [4] pointed out that the figures 2.00 given 2ft3/ft2/day for canal 5 on sandy soil and 0.07 ft3/ft2/day lined canals were correct.

Sharma and Sehgal [7] studied the assessment of seepage from unlined irrigation channels and concluded that the seepage losses were 1.8 cumec/Mm2 against the as against the assumed losses of 2.4 cumec/Mm2. Percentage of water lost from main branch of canal system was found to be 19 percent as against 18 percent usually assumed. Total seepage from both sides of canal was found to be 6/5 times the maximum intensity of seepage at the bottom.

Anonymous [8] observed that seepage values were ranging between almost nil to 4.26 cumec /Mm2 from distributaries. Sharma et.al [7] observed that aquatic weed problem in irrigation system situated in south-eastern part of Rajasthan and West Madhya Pradesh was increased to such an extent that it caused 20 to 60 percent reduction in carrying capacity.

Anonymous [9] reported the seepage losses through unlined canals in India as 3 to 7 cumec /Mm2 and concluded that losses by seepage depend mainly on the wetted perimeter of the section and the nature of the inner face of the section i.e. whether it is lined or unlined.

Luthra [10] found that the conveyance losses in the unlined canals varying between 25-60 percent and the seepage losses in case of lined canal system were restricted depending on type of material used for lining. Raju [11] reported seepage loss from lower Bhavani distributor as 16 to 20 percent of the canal discharge. Anonymous [9] carried out the studies on canal losses on Mula Right Bank Canal and seepage losses were found to be 7.8 cumec / Mm2 tream canal and 4.26 cumec / Mm2 from distributaries.

Bihari and Patel [12] studied the conveyance losses in earthen channel and concluded that apart from steady state seepage, there could be a significant transit loss component that is not measured in steady state measurements. These include rapidly infiltrated water to wet up dry channel banks, water seepage and leakage during the time water was being transferted from one field to another, dead storage losses resulting from water course breaches and due to growth of grasses in the channel.

Rajput and Ashwani Kumar [13] studied conveyance losses in the field water courses. The loss from field water courses alone was measured to be about 20 percent of canal discharge.

Sur. et.al. [14] reported that conveyance losses and efficiency in unlined field channels in the command area of Bhaini Distributory in South Western Punjab. Overall losses from the studied channels were 24.2% Conveyance efficiency decreased exponentially with increase in the length of channel. The results suggested that additional 18 minutes per hour per kilometer of channel length will be required to receive same amount of water at different field outlets along the channel.

Tiwari and Pant [15] studied the seepage losses through farm ponds. Six farm ponds of 100 m3 capacity were constructed and their seepage rates observed during monsoon and post monsoon periods. During monsoon, the water table was observed to be close to the pond bottom which restricted vertical flow of water and sometimes negative seepage was observed. Ponds lined with low density polythelene film gave the lowest seepage rate compared with pointed brick lining and cement soil lining materials.

Kacimav A.R. applied a complex variable method and series expansions to optimal shape design problems for a channel bed. A dimensionless depth of trapezoidal and rectangular channel were determined by minimizing the cost function. The cost function included seepage losses and cost of lining.

Achanta Rao [16] conducted experiments to find the effects of seepage on inflow over a sand bed in a straight rectangular flume. Effects of both injection and suction caused by seepage flow into and out of the channel bed were studied. Quantitative relationships giving the ratio of bed shear stresses with and without seepage were presented.

Bankar et.al [17] estimated seepage losses of irrigation water through minor and field channels by inflow outflow method under On Farm Water Management Studies in Mula Command during kharif, rabi and summer seasons of the year 1991 – 92 and 1992 – 93. The study revealed that by simple cleaning of field channel the seepage losses could be reduced by 40 percent over unclean channel. Due to lining of field channel the seepage losses could be further reduced by 36 to 61 percent over cleaned and unclean filed channels, respectively, During kharif season there were comparatively more seepage losses of water (21.44 1ph/m2) than in rabi (18.79 1ph/m2) comparison of seepage losses amongst lined. Cleaned and uncleaned field channels in various seasons indicated that lining of field channel resulted into minimum loss of water (11.65 ph/m2) through seepage followed by cleaned field channel and maximum was due to uncleaned field channel (3024 1ph/m2)

Dhotre et.al [18] Studied the field evaluation of seepage losses through field channel at College of Agricultural Engineering M.P.K.V.Rahuri. Seepage losses in lined and unlined field channels were 1.64 and 3.62 cumec / Mm2 respectively. He also suggested that if lining was provided the losses could be reduced to 1.64 cumec / Mm2 which is 54.70 percent less compared to unlined field channels.

Anonymous [19] studied theponding tests to observe seepage losses in lined and unlined canal sections and investigated what type of lining materials would be more effective, durable and suitable for the construction of irrigation canals. Ponding tests revealed that the unlined canal section had the highest rate of seepage loss. The brick lining on compacted soil had the highest rate of seepage loss followed by brick lining on cement mortar, tile lining, concrete lining and asphalt lining.

2.2. Seepage loss through different lining materials

Ponnaiya [20] carried out studies on seepage losses in field channels with various lining materials. The seepage loss determined by the Inflow- Outflow method varied from 0.225 to 0.315 ft3/ft2/h whereas in still port water level method it varied from 0.1954 to 0.2584ft3/ft2/h The constant rate of seepage loss in 200 ft length of unlined earthen channel was found to vary from 12 to 18 percent of the inflow into the channel i.e. 0.23 to 0.41 ft3/ft2/h of wetted area. Anonymous [21] conducted semi – field trials on lined channels.

They use following treatements:

1. Cement–surkhi-sand-gravel concrete (0.58 :0.15 :5:10)
2. Cement – flyash-sand-gravel concrete (0.8 : 0.2 : 5 : 10)
3. Sand –asphalt – cement lining on soils base (0.85 : 0.1 : 0.05)
4. Sand- asphalt – cment lining on cement mortar base (0.85 : 075 : 0.075) and
5. Unlined.

They observed that maximum seepage was recorded in unlined channel i.e. 45 cumec per 1000 m2 and minimum seepage was in treatment No. 2 i.e. 2.76 cumec per 1000 m2

Irrigation Commission, India (1972) assumed channel loss of 2.44 cumec / Mm2 for designing a channel with lining, the depending upon nature of lining. The commission further recommended that in all future projects the main canals and branches in general should be provided with lining.

Committee of Research of Irrigation and Drainage Division (1974) reported that lining of channels to reduce seepage decreases roughness coefficient resulting in a smaller converance cross and shorter trains time.

Anonymous [22] conducted experiments to work out seepage and evaporation losses in canals. The canal was lined with lime – surkhi – sand and gravel (1 : 1 : 1 : 2) concrete finished with 12mm plaster and without plaster. Seepage and evaporation losses were worked out to be 0.17 cumec / Mm2 and 0.25 cumec / Mm2 in former and later respectively.

Anonymous [22] conducted experiment on seepage losses through experimental channels under semi –

field conditions lined with different lining materials. The seepage losses of various lining specifications varied from almost nil to 0.3 cumec/Mm2 in double layer tile lining with sandwich of 1:3 cement sand plaster at the side slope and single layer brick at bed and asphaltic concrete 6.8 cm thick respectively.

The seepage losses through precast blocks of single layer brick lining 1:3 cement mortar ranged from 0.04 to 0.16 cumec / Mm2.

Anonymous [22] conducted laboratory tests on asphaltic concrete lining consisting of pea jelly, quarry dust fine aggregate rock dust (20 : 40 : 25 : 10) and 60/70 maxphalt 9 percent by weight and cement concrete 1:4:8 with 13 percent bentonite and found that these can serve as good lining materials.

Krantz et.al [23] observed that amongst the conveyance losses resulting from seepage, leakage through structures and spills due to poor operation of gates and over delivery due to faulty meter measurement, the seepage losses were highest. He concluded that this could be controlled by some form of lining subject to economic feasibility.

Mclaughlin and et.al [24] experimentally proved that on asphalt emulsion mixed with soil has shown promise as a lining material.

Worsteel R.V. [25] conducted the tests on various lining materials to study the seepage losses and found the range of seepage losses through different lining materials as below:

1. Concrete (0.009 to 0.29) m/day)
2. Compacted earth (0.003 to 0.29 m/day)
3. Asphalt membrance (0.003 to 0.92 m/day.
4. Soil cement (100 : 5) (0.009 to 0.06 m/day.
5. Chemical Sealant (0.1 to 2.53 m/day)
6. Sediment Seal (0.12 to 0.40 m/day)
7. Unlined (0.003 to 5.37 m/day)

Krantz [23] reported an average of 17.5 per cent loss of flow as seepage per km of irrigation channels (20 to 100 1 ps) in western Greece.

Ali [26] discussed briefly the value of water course maintenance channel improvement pucca lining of channels, precision land leveling and irrigation advisory service in improving the efficiency of water use.

Anonymous [27] conducted the experiments at Maharashtra Engineering Research Institute Nasik to evolve cheap canal lining material in the form of stabilized soil tile with mortar facing and also fly ash concrete. It was observed that fl ash is uniform in properties except that of fineness even though, coal used has varied in its properties to wide extent.

It was observed that cement could be replaced by fly ash upto 10 percent in case of 1 : 3 and 1 : 5 mortars and sand can be replaced by fly ash up to 20 percent in case of 1 : 3 and 1 : 5 mix. The study was made on strength criterion and found that if 90 days was strength criterion then 20 per cent cement would be replaced for major works like dams and if 28 days was the strength criterion then 15 per cent cement could be replaced by fly ash. The fly ash has been used in stabilized soil as support for tiles. The technique is already being adopted in Jaikwadi and Girna Command Areas.

Das [28] reported that 0.3 m rubble lining having 0.23 m surface grouted with concrete and literate 0.15 m thick block lining have proved economical and effective in expansive soils. Dwivedi and Sarkar [29] conducted the field experiments at water technology Center. I.A.R.I. New Delhi to study the seepage losses through water tanks. They used following different lining materials in tanks:

1. Brick lining with cement pointing.
2. Hot applied asphalt lining.
3. Lime – fly ash – soil (1 : 2 : 24) lining with cement slurry.
4. Cement – mortar (1 : 6) on lime – fly – ash – soil (1 : 2 : 24) base.
5. Polyethylene lining with 15 cm soil cover.
6. Unlined.

They concluded that the highest seepage losses werein unlined tank and the lowest seepage losses were in cement mortar (0.024m3/m2/day) (1:6) lining. It was followed by polyethylene lining 0.068 m3/m2/day, brick lining 0.102 m3/m2/day, lime – fly ash – soil (1:2:24) lining 0.127 m3/m2/day and hot applied asphalt lining 0.161 m3/m2/day. They compared the theoretically calculated values of seepage flow rate with observed values and found that the former were lower than later by 34 percent.

Suryawanshi et al [30] studied the seepage losses through different channel lining materials which were as follows:

Ταβλε 2.1 Σεεπαγε λοσσ τηρουγη διφφερεντ λινινγ ματε ριαλ

S N	Lining Material	Average Specific Seepage loss (1ph/m^2)	Steady Specific Seepage loss (1ph/m^2)
1	Earthern	26.76	18.00
2	Brick in mortar	22.18	12.00
3	Fly ash (cement 1. Fly ash 2.5 and sand 2.5)	16.84	8.15
4	Cement Concrete	14.32	11.20
5	Soil Cement (10.1)	8.39	6.45
6	Polyethylene sheet of 400 gauge covered with soil	6.82	5.00

Atre and Sarap [31] studied seepage losses for different channel lining materials. They concluded that the velocity of flow was maximum in polyethylene channel (91.99) cm/sec) Manning's roughness coefficient was found to be minimum in case of polyethylene channel (0.008) The seepage losses were maximum in in earthen channel to the tune of 1.57 m/day and minimum in polyethylene channel as 0.014 m/day.

Khair and Dutta [32] studied the scope for using bituminous (asphatic) materials to line small irrigation canals. Two types of prefabricated asphalt matsshowed promise as canal liners for minor irrigation project areas:

1. Gunny (coarse sack cloth made of jute) reinforced asphalt mat.
2. Synthetic cloth (fertilizer bag made of synthetic fiber) reinforced asphalt mat. With the asphalt mat daily seepage losses were reduced from 1.01 m3/m2 to 0.0030 to 0.0035 m3/m2 for unlined canal.

Nema [33] conducted experiments to evaluate the effectiveness of different channel lining materials. Analysis revealed that by compacting the channel surface up to a bulk density of 1.9 g/cc seepage losses can be checked up to 74.89 percent as compared to that in an unlined channel. This treatment was found most economic and feasible amongst other lining material tried in the study.

Narda and Gulati [34] studied that seepage losses of irrigation water from unlined field channel. A seepage loss function was developed by fitting discharge loss data and conveying distance to and exponential relationship, which produced a conveying efficiency of 57.6 percent.

2.3 Channel section & prefabricated concrete lining

Varshney et al [35] reported that concrete was popular material for canal lining as excellent hydraulic properties were attained by its use. Yazdani et.al [36] concluded that by lining the unlined channels with concrete 50 percent of the present losses can be saved. Das [28] reported that semicircular channels having inner diameter 30.5 cm and thickness 3.75 cm are mostly used for low discharge. He designed the semicircular channel with collar which accepted the tail of the other channel. Dr. Mehta, et.al [37] stated that irrigation potential from known sources of water could be almost doubled by preventing seepage losses by lining distribution canals. Michael [1] reported that the area of land occupied by channel was greatly reduced when precast concrete channels were used since side embankments were not necessary.

Nagarkar et.al [38] used fly ash to supplement the fines in concrete to minimize cost of concrete lining. They found that the concrete tiles of proportion (1:3:6:9) could be manufactured satisfactorily and this concrete was economical to the extent of 25 to 30 percent.

Gwinn and Ree [39] conducted experiments on grass lined channel and observed that the stability and capacity of channel were related to changes in cover. They conducted flow tests of channels with natural encroachment of bush and trees and found that encroachment of bush reduced the flow capacity by 29 percent.

Michael et.al [40] investigated the feasibility of use of unconventional materials like lime, Surkhi, plaster of pairs, fly ash, cement, sand, gravel for precast channels. The study revealed that the minimum seepage of 2 lit/m2/day was found in lime – fly ash – gravel (1:1:2) mixture and maximum seepage rate of 16 lit/m2 day was found in case of lime – surkhi-gravel (1:3:3) mixture.

3. Material and methods

For the study of seepage losses sections of lined Paithan Left Bank Canal (PLBC) lined minor under the command area of Jaikwadi Project. Unlined Lasina Left Bank Canal unlined minor under the command area of Yeldari project have been selected.

3.1 Selection of sections of canal & minor

Uniform sections of canal which were free from lifts, outlets and other obstructions were selected for the measurement of seepage loss.

In case of lined canal three sections of PLBC having lengths of abont 710, 850 and 910 m were selected. Canal was concrete lined. In case of unlined LLBC three sections of 1000 m in length were selected. In case of lined minor three sections of length 300, 800 and 800 m were selected for the study. Minors were concrete lined. Three sections of unlined minor having lengths 480, 540 and 650 m were selected.

3.2 Measurement of canal

When the canal was dry all the dimensions such as depth of canal, bottom width, top width, side slope, etc have been taken. The maps of both lined Paithan Left Bank Canal and unlined Lassina Left Bank Canal were collected from Irrigation Department.

3.2.1 Measurement of velocity

Velocity of flow of water in canals and minors was measured with the help of current meter. The current meter was suspended by means of a cable and it was held vertically immersed in the flowing stream of water to the required depth (0.6 of depth of flow) such that the wheel was facing towards the upstream direction. The wheel was then rotated by the dynamic thrust exerted on it by the flowing water. The no. of revolution of wheel was kept constant and time required for it was noted and from calibration chart the velocity of flow of water was determined. Measurements of velocity were taken at the upstream and downstream end of each section.

3.3 Measurement of discharge

In order to obtain the discharge through the canal and minor the cross section of the canal and minor was divided into number of equal segments as shown in definition sketch. The mean depth of flow of the segments was measured by measuring tape and the mean velocity of flow through each segment was measured with the help of current meter by inserting it to a depth of equal to 0.6 times the mean depth below the free water surface. Flow velocities at the left and right edges of stream (at the bank) were assumed as zero.

Then according to Simpson's rule total discharge through the canal was determined. Simpson's rule is shown in eq(3.1).

The discharge through the sections, of canal and minor was calculated by multiplying the cross – sectional area to the mean velocity of flow of water.

3.4 Measurement of seepage loss

The seepage loss through the sections was computed by inflow outflow method:

$$\text{Seepage loss } (I) = \frac{\mathrm{Q_1 - Q_2}}{\mathrm{A}}$$

I = Seepage loss, cumec/Mm^2 of weted area.
Q_1=Discharge at upstream end (inflow) cumec
Q_2=Discharge of downstream end (outflow) cumec.
A=Wetted area, Mm^2.

3.5 Measurement of wetted area

To determine the wetted area of sections, the top width and depth of flowing water were measured with the help of measuring tape at different points at an equal interval and wetted perimeters were determined at these points.

Wetted area =(Average of wetted perimeter) X (length Of sections between observation points)

3.6 Determination of roughness coefficients

Roughness coefficients of all selected sections were determined by using following formulae

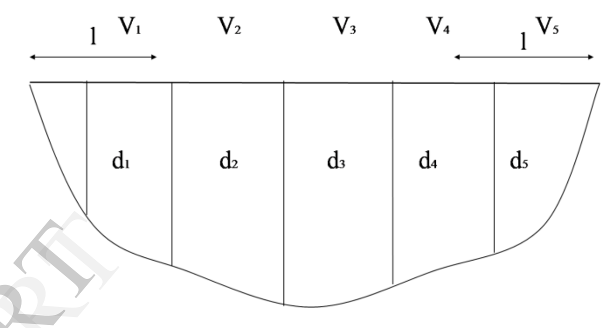
i) Manning's formula
ii) Chezy's formula
iii) Darcy – weisbach's formula

Formulae are as follows

i) Manning's 'n' $= \frac{\mathrm{R^{2/3} - S^{1/2}}}{\mathrm{V}}$
ii) Chezy's 'C' $= \frac{\mathrm{V}}{\sqrt{\mathrm{RS}}}$
iii) Darey – Weisbach's f $= \frac{8\,\mathrm{g\,R\,S}}{\mathrm{V}^2}$

Where,
R = Hydraulic radius, m
S=Hydraulic slope m/m.
V=Mean velocity of flow in the channel, m/sec.
g=Acceleration due to gravity, $\mathrm{m/S}^2$.

3.7 Measurements of discharge



d_1, d_2, d_3, d_4 and d_5 are the depths at the end of each segment and v_1, v_2, v_3, v_4 and v_5 are the velocities at the end of segments.

Φιγυρε 3.1 Δεπτη & ϖελοχιτιεσ ατ ϖαριουσ σεγμε ντσ

Simpson's rule:

$$Q = \frac{l}{3}(0 + 4\mathrm{d_1V_1} + 2\mathrm{d_2V_2} + 4\mathrm{d_3V_3} + 2\mathrm{d_4V_4} + 4\mathrm{d_5V_5} + 0 \ldots\ldots\ldots\ldots (3.1)$$

l is the length of the segment. Velocity at the bank is taken as zero.

4. Results and discussion

The seepage losses through selected sections of lined and unlined canal and minor were measured by adopting the procedures as explained in Chapter III. The present chapter includes the data collected. Their analysis and interpretation in light with the literature reviewed.

4.1 Measurement of canal & minor

4.1.1 Measurement of sections of canal

Each section was divided into five subsections and measurements like cross sectional area, top width, depths of flow and wetted perimeter were measured at these subsections. The observations were made when the canal was flowing. The the average of these readings were made at inlet and outlet section by dividing the canal width into six segments of equal length and taking readings at the end of each segment. The average of velocities at inlet and outlet section was considered. The observations were recorded in respect of lined PLBC and unlined LLBC canal and are presented in table 4.1 and 4.2. The view and measurements of flowing lined Paithan Left Bank Canal are shown in plate 4.1 and Plate 4.2.

Ταβλε 4.1 Μεασυρεμεντ οφ λινεδ χαναλ

Section	Length of Section (m)	Depth of flow (m)	Bed Slope (%)	Av e/s Area (m^2)	Av wetted perimeter (m)	Av Velocity (m/s)
I	710	0.69	0.033	8.450	13.602	0.74
II	850	0.85	0.033	10.553	13.980	0.91
III	910	1.28	0.033	16.124	14.954	1.20

Ταβλε 4.2 Μεασυρεμεντ οφ υνλινεδ χαναλ

Section	Length of Section (m)	Depth of flow (m)	Bed Slope (%)	Av e/s Area (m^2)	Av wetted perimeter (m)	Av Velocity (m/s)
I	1000	1.04	0.038	7.630	10.879	0.61
II	1000	1.21	0.036	12.054	14.174	0.72
III	1000	1.41	0.035	16.493	16.725	0.79

The view and measurement of unlined left bank canal are shown in plate 4.3 and plate 4.4 and measurement of velocity by current meter is also shown in plate 4.5.

It is seen from Table 4.1 that the depth of flow was observed to be varying between 0.69 to 1.28 m/s for the three sections of lined canal. Table 4.2 reveals that for the unlined sections of canal the depth of flow was observed to be varying between 1.04 to 1.41 m resulting in corresponding velocities of 0.61 to 0.79 m/s. The average cross- sectional area for the lined sections of canal were found to be 8.450, 10.553 and 16.124m2 for unlined sections of canal.

4.1.2 Measurement of sections of minor

The wetted sections of lined and unlined minor were measured by procedure as explained in case of canal. Current meter readings were made at inlet and outlet sections of minor by dividing the minor width into four segments of equal length and taking readings at the end of each segment. The average of velocities at inlet and outlet sections was considered. The observations were recorded in respect of lined minor and unlined minor. The observations are given in Table 4.3 and 4.4

Ταβλε 4.3 Μεασυρεμεντ οφ λινεδ μινορ

Section	Length of Section (m)	Depth of flow (m)	Bed Slope (%)	Av e/s Area (m^2)	Av wetted perimeter (m)	Av Velocity (m/s)
I	300	0.43	0.0166	0.744	2.51	0.39
II	800	0.39	0.0225	0.660	2.39	0.37
III	800	0.59	0.0131	1.450	3.54	0.50

Ταβλε 4.4 Μεασυρεμεντ οφ υνλινεδ μινορ

Section	Length of Section (m)	Depth of flow (m)	Bed Slope (%)	Av e/s Area (m^2)	Av wetted perimeter (m)	Av Velocity (m/s)
I	540	0.49	0.0462	1.180	4.01	0.36
II	480	0.62	0.0416	2.105	5.08	0.46
III	650	0.67	0.0415	2.300	5.24	0.47

Table 4.1 to 4.4 show that the depth of flow in unlined section of canal and minor were more as compared to lined section of canal and minor. Average velocities of flowing water were found be less in case of unlined section of canal as compared to lined canal section. This is because due to sides of earthen canal being more rough and thus resist the flow of water as compared to lined canal and minor. In case of lined canal and minor the lining was smooth and offered least resistance to the flow of water. This is in conformity with the observations made by Atre and Sarap (1988).

4.2 Measurement of seepage loss

4.2.1 Seepage loss through canal

The data on discharge and the seepage losses in lined and unlined canal is given in Table 4.5 and 4.6.

Ταβλε 4.5 Σεεπαγε λοσσ τηρουγη λινεδ χαναλ

Section	Length of Section (m)	Depth of flow (m)	Bed Slope (%)	Av e/s Area (m^2)	Av wetted perimeter (m)	Av Velocity (m/s)
I	710	6.237	6.230	9657.	0.80	--

		82	09	42		
II	850	9.546 44	9.536 69	11883 .00	0.82	0.836
III	910	18.85 784	18.84 572	13608 .14	0.89	--

Ταβλε 4.6 Σεεπαγε λοσσ τηρουγη υνλινεδ χαναλ

Section	Length of Section (m)	Depth of flow (m)	Bed Slope (%)	Av e/s Area (m^2)	Av wetted perimeter (m)	Av Velocity (m/s)
I	1000	4.90 7	4.83 7	10932. 54	6.40	7.063
II	1000	9.24 1	9.13 6	14196. 56	7.40	
III	1000	13.6 12	13.4 90	16508. 79	7.39	

From Table 4.5 it is seen that for the first section, the discharge at the u/s end d/s end was found to be 6.23782 and 6.23009 cumec. Respectively resulting into corresponding seepage losses of 0.80 cumec/Mm^2 wetted area of canal. The values of seepage losses for II and III sections were found to be 0.82 and 0.89 cumec/Mm^2 respectively. It is observed that seepage loss was nearly same at these sections of canal.

Table 4.6 reveals that the discharge at the u/s end was verying between 4.907 to 13.612 cumec resulting in corresponding seepage losses as 6.4 to 7.39 cumec/Mm2 wetted area of unlined canal. These results are in conformity with those made by Anonymous [9].

4.2.2 Seepage loss thorough minor

The data on discharge at the two ends of the lined section of minor along with seepage losses is presented in Table 4.7

Ταβλε 4.7 Σεεπαγε λοσσεσ τηρουγη λινεδ μινορ

Section	Length of Section (m)	Depth of flow (m)	Bed Slope (%)	Av e/s Area (m^2)	Av wetted perimeter (m)	Av Velocity (m/s)
I	300	0.29 57	0.29 35	755.8 1	2.91	3.01
II	800	0.24 67	0.24 08	1911. 50	3.09	
III	800	0.72 27	0.71 41	2832. 80	3.03	

The seepage losses for the I, II and III section of lined minor were found to be 2.91, 3.09 and 3.03 cumec/Mm2 wetted area of minor respectively.

In case of unlined minor the observations on three different sections were recorded and age given in Table 4.8

Ταβλε 4.8 Σεεπαγε λοσσεσ τηρουγη υνλινεδ μινορ

Section	Length of Section (m)	Depth of flow (m)	Bed Slope (%)	Av e/s Area (m^2)	Av wetted perimeter (m)	Av Velocity (m/s)
I	540	0.45 98	0.44 95	2165. 94	4.76	4.93
II	480	1.04 82	1.03 71	2425. 05	4.57	
III	650	1.19 64	1.17 78	3402. 04	5.47	

The seepage losses for I, II, and III section of unlined minor were found to be 4.76, 4.57 and 5.47 cumec/Mm2 wetted area of minor respectively.

In case of lined and unlined canal, the average seepage losses were 0.836 and 7.063 cumec/Mm2 respectively. This study revealed that if lining is provided the seepage losses could be reduce by nearly 88.16%.

The average seepage losses were 3.10 and 4.93 cumec/Mm2 in lined and unlined minor respectively. If lining is provided for minor. The seepage losses could be reduced by nearly 38.94 % the results are in agreement with those reported by Anonymous (1984) and Benker et al. (1995)

4.3 Determination of roughness coefficient.

The data on cross-sectional area. Wetted perimeter bed slope velocity of flowing water in canal and minor is presented in Table 4.1 to 4.8. The roughness coefficients as suggested by Manning. Chezy and Darcy-Weisbach were computed from this data and are presented in Table 4.9 to 4.12.

Ταβλε 4.9 Ρουγηνεσσ χοεφφιχιεντσ (λινεδ χαναλ)

Section	Manning's 'n'	Chezy's 'c'	Darcy-Weisbach 'f'
I	0.01806	51.14	0.300
II	0.01672	57.05	0.0241
III	0.01608	62.94	0.0198
Average	0.01695	57.04	0.114

Ταβλε 4.10 Ρουγηνεσσ χοεφφιχιεντσ (υνλινεδ χαναλ)

Section	Manning's 'n'	Chezy's 'c'	Darcy-Weisbach 'f'
I	0.2522	37.37	0.0562
II	0.2362	41.15	0.0463
III	0.2346	42.52	0.0434
Average	0.0241	40.34	0.0486

Ταβλε 4.11 Ρουγηνεσσ χοεφφιχιεντσ (λινεδ μινορ)

Section	Manning's 'n'	Chezy's 'c'	Darcy-Weisbach 'f'
I	0.01499	55.49	0.0255
II	0.1719	46.94	0.0356
III	0.01263	68.19	0.0169
Average	0.01493	56.87	0.026

Ταβλε 4.12 Ρουγηνεσσ χοεφφιχιεντσ (υνλινεδ μινορ)

Section	Manning's 'n'	Chezy's 'c'	Darcy-Weisbach 'f'
I	0.2644	30.84	0.825
II	0.2472	35.01	0.0640
III	0.02504	34.81	0.0648
Average	0.0254	33.55	0.0704

4.3.1. Manning's roughness coefficients

From Table 4.9 and 4.10 it can be said that computed values of Manning's varied from 0.01608 to 0.01806 and 0.02346 to 0.02522 for lined and unlined sections of canal respectively. The recommended values for concrete lining material and earthen canal are 0.017 to 0.020 and 0.025 respectively.

4.3.2 Cehzy's roughness coefficients

From the table 4.9 and 4.10 it can be said that completed values of Chezy & C varied that 51.14 to 62.94 and 37.37 to 42.52 for lined and unlined sections of canal respectively.

4.3.3 Darcy-Weisbach's roughness coefficients

It is also seen from table 4.9 and 4.10 that completed values of Darcy-Weisbach & f varied from 0.0198 to 0.300 and 0.0434 to 0.562 for lined and unlined canals respectively.

Average values of Manning's n, Chezy's C and Darcy's F for lined canal are 0.01695, 57.04 and 0.114 respectively and for unlined canal these average value are 0.0241, 40.34 and 0.04876 respectively.

From table 4.11 and 4.12 reveal that the values of Manning's n values from 0.01263 to 0.1719 and 0.2472 to 0.02644 for lined and unlined minors respectively. The values of Chezy's C values from 46.94 to 68.19 and 30.84 to 35.01 for lined and unlined minors respectively and the values of Darcy's – weisbach – f values from 0.0169 to 0.0356 and 0.040 to 0.0825 for lined and unlined minors respectively.

The average values of Manning's n are 0.01493 and 0.0254 for lined and unlined minors respectively. The average value for Chezy's C are 56.87 and 33.55 for lined and unlined minors respectively. The average Darcy-Weisbach's 'f' was found to be 0.114 and 0.0486 for lined and unlined canal, respectively.

Table 4.11 and 4.12 reveal that the average values of Darcy-Weisbach's roughness coefficient was found to be 0.026 and 0.0704 for concrete lined and unlined minor, respectively. It is also observed that there was inverse relationship between Darcy – Weisbach's roughnes coefficient and velocity of flowing water.

5. Conclusions

An experiment entitled, "studies on seepage losses through canals and minors" was undertaken at the site of Paithan Left Bank Canal and Lassina Left Bank Canal.

Seepage losses were calculated by inflow-outflow method. Three roughness coefficients (Manning, Chezy and Darcy Weisbach) were computed using the data, velocity hydraulic radius and slope of canal and minor.

Followings conclusion could be drawn from the findings of the present study.

1. Velocities of flowing water were found to be maximum in lined canal and minor as compared to unlined canal and minor.
2. Maximum seepage loss was found to be 7.40 cumec/Mm2 in the second section of unlined canal and minimum seepage loss was found to be 0.80 cumec/Mm2 in first section of lined canal.
3. Average seepage losses in lined and unlined canal were 0.836 to 7.063 cumec/Mm2 respectively. If lining is provided the seepage losses could be reduced by nearly 88.16%.
4. Average seepage losses in lined and unlined minor were 3.01 and 4.93 cumec/Mm2 respectively. If lining is provided the seepage losses could be reduced by nearly 38.94%.
5. Average Manning's roughness coefficient for lined and unlined canal were 0.01695 and 0.0241 respectively.
6. Average Manning's roughness coefficient for lined and unlined minor were 0.01492 and 0.0254 cumec/Mm2 respectively.
7. Average Chezy's roughness coefficient for lined and unlined canal were 57.04 and 40.34 respectively.
8. Average Chezy's roughness coefficient for lined and unlined minor were 56.87 and 33.55 respectively.
9. Average Darcy – Weisbach's roughness coefficient for lined and unlined canal were 0.114 and 0.0486 respectively.
10. Average Darcy-Weisbach's roughness coefficient for lined and unlined minor were 0.026 and 0.0704 respectively.

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