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STUDY OF CANAL SEEPAGE AND CANAL LINGING A CASE STUDY OF KHADAKWASLA RIGHT BANK CANAL

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Abstract: In India, canal irrigation stands as a significant source of artificial irrigation. Numerous canals remain unlined, resulting in substantial seepage. Seepage rates of 50 to 60% are commonly observed in unlined canals. Materials such as concrete, shotcrete, and stones are typically used for canal lining. Concrete can mitigate seepage losses by up to 70%, while shotcrete can be even more effective, reducing losses by up to 90%. However, these materials require maintenance due to the occurrence of expansion and contraction cracks. HDPE sheets offer a promising solution to reduce seepage losses through cracks in concrete lining. The Indian government also offers subsidies for the use of these sheets as lining materials. Concrete and shotcrete can serve as protective coverings for HDPE, shielding it from external damage caused by stones and crawling animals. Canals featuring a combination of HDPE and concrete lining represent an optimal solution.

By employing this combination of materials, it is possible to save 100% of water while simultaneously expanding the irrigable area. Additionally, the installation of sensor systems along the canal can facilitate the monitoring of discharge and water levels at various sections. Radar and bubbler systems are particularly effective for this purpose. Consequently, seepage points can be easily identified at any section of the canal. Through the integration of HDPE sheets and sensor technology, seepage losses in canals can be reduced by up to 100%, leading to significant benefits such as water conservation and increased agricultural productivity.

INTRODUCTION

Efficient management of water within an irrigation system necessitates a thorough understanding of the water flow within the canal. This knowledge enables the delivery of the appropriate amount of water to each user at the right time, minimizing losses and preventing physical and environmental harm. Seepage losses from canals pose a challenge to the optimal functioning of the canal system, as this water seeps out of the canal, flows downhill, and infiltrates through soil layers, potentially becoming inaccessible to water users. Moreover, seepage can undermine effective water management by causing erosion and piping damage at control structures.

Canals remain vital conduits for supplying water for irrigation purposes. The loss of water through seepage from irrigation canals accounts for a significant portion of the available water (Rohwer and Stout 1948). According to the Indian Bureau of Standards (IBS) (1980), seepage losses from unlined canals in India typically range from 0.3 to 7.0m3/s per 106 m2 of wetted surface area. Seepage loss from canals is influenced by factors such as the hydraulic conductivity of the subsoil, canal geometry, physical condition of the canal, water table position relative to the canal, and various other factors [International Commission on Irrigation and Drainage (ICID) (1967)]."

Irrigation Canals:-

Canals utilized for irrigation purposes are referred to as irrigation canals. Canals can be described as man-made channels built on the ground to transport water from one location to another. These canals may be categorized as either alluvial or non-alluvial, depending on the soil type. They may also be distinguished as inundation canals or permanent canals, based on the method of water supply from one system to another."

Classification of canal:-

1. Alluvial Canal:-

   A canal flowing through alluvium soil (silt, sand and gravel) is called an alluvial canal. A canal flowing through such sediments transports some of this material along with the flowing water. These canals take supplies from rivers which always carry sediments rolling on the bed or held in suspension , which is passed on to the off-taking canals . If the velocity in a canal is very high, the suspension particles are not deposited, but if the velocity is very low, the sediment held in suspension will get deposited.

2. Non Alluvial Canal:-

   Non alluvial canals are those that have been lined with some suitable material to provide a rigid bed banks so as to avoid the problems with alluvial sides (boundaries) of a canal.

3. Inundations canal:-

   These canals depend for their supplyon the periodical rise in the water level of the river from which they are taken off. The supplies of these canals are not always of the desired level .these canals are fill with water in Rainy season or in monsoon.

OBJECTIVES OF PROJECT

The objective function is based on minimum water loss from a canal cross section due to seepage and evaporation. There are two main sources of water loss. The seepage depends upon the wetted perimeter and depth of flow whereas evaporation is function of top width of the flow section.

The main objectives of the project are given below:-

I. The purpose of this Project is to present the main considerations regarding lining KHADAKWASLA canal.

II. To estimate seepage losses of KHADAKWASLA canal followed by a description of the most commonly used lining methods.

III. To estimate the expected cost of implementing the recommended types of lining to KHADAKWASLA canal according to some alternative schemes,

IV. To evaluate the benefits produced by the lining and calculate the corresponding benefit/cost ratio.

V. To study the principal reasons for considering the lining

LITERATURE REVIEW

INTRODUCTION

Surveys of various papers, research, different results computed that seepage losses are more in unlined canals as well as lined canal. Many authors and researchers found that different geomembrane reduces seepage losses in unlined as well as lined canal.

REVIEW OF PAPERS

Magdy H. Mowafy, *SEEPAGE LOSSES IN ISMAILIA CANAL Water Engineering Department, Faculty of Engineering, Zagazig University, Egypt Sixth International Water Technology Conference, IWTC 2001, Alexandria, Egypt*

- It isevaluated that seepage losses at different critical sections of Ismailia Canal which transports fresh water from River Nile at north of Cairo to Ismailia, Port Said and Suez cities with discharge of 433.56m^3/sec using different empirical, analytical and field measured results.
- The computed results which agree with measured results are discussed to deduce a formula available to compute seepage losses in the future and found that the results of computed seepage losses by empirical formulae of Molesworth and Yennidunia and Hungarian, and by all analytical equations give good results when compared with different field measured results.

Ms. K. D. Uchdadiya, Dr. J. N. Patel, *Seepage losses through unlined and lined canalsInt. J. Adv. Appl. Math. AndMech. 2(2) (2014) 88 - 91 (ISSN: 2347-2529)*

- The losses from canals need to be minimized to ensure the efficient performance and effective utilization of water. Seepage loss is one of the major components of water loss from canals. Seepage rates are obtainable either by direct measurement or by estimation. Measurement of seepage from large canals by ponding method is practically impossible due to continuous running and large widths of canals.
- Inflow-outflow method is also not suitable for canal seepage measurement in short reaches of canals due to small differences. Seepage meter technique may require a large number of measurements to arrive at an average value of canal seepage.
- Analytical solutions are over simplified for estimation of canal seepage due to several assumptions which are rarely met in the field. During this investigation the seepage analysis of unlined and lined irrigation canal has been done depending on equations derived by Swamee et al. Average seepage losses in the unlined canal are 0.415 comic, in Brick lined canal are 0.0511 comic, in P.C.C. lined canal are 0.0028 comic and in P.C.C. with LDPE film lined canal are 1.2_10□4 comic. If lining is provided the seepage losses could be reduced by nearly 87.68%, 99.30%, and 99.97% respectively.

KavitaKoradia, Dr. R B Khasiya, *Estimate Seepage Losses in Irrigation Canal System, INDIAN JOURNAL OF APPLIED RESEARCHMAY 2014*

- The conveyance efficiency in irrigation projects is poor due to seepage, percolation, cracking, and damagingof the earth channel. Seepage loss in irrigation water conveyance system is very significant, as it forms the majorportion of the water loss in the irrigation system.
- One of the main problems that meet the Ministry if Irrigation and Water Resources is that about 80% from its total length passing through silt clay soil. The quantity of seepage to surrounding areavaries from section to other. The seepage losses affect the water surface profiles, slops, discharge, and water level. .
- Variousmethods are used to estimate the canal seepage rate. The main objective of this research are evaluating seepage losses at different critical sections and comparing between different empirical, analytical and field measure result.

Prabhata K. Swamee, Govinda C. Mishra And Bhagu R. Chahar, *DESIGN OFMINIMUM SEEPAGE LOSS CANAL SECTIONSJOURNAL OF IRRIGATION AND DRAINAGE ENGINEERING / JANUARY/FEBRUARY 2000*

- SCOPE
- It showed that on account of additional cost of excavation with canal depth the optimal section is wider and shallower than the minimum area section and increased lining cost the optimal canal section approaches to the minimum area section.
-

Jay Swihart Jack Haynes *CANAL-LINING DEMONSTRATION PROJECT YEAR 7 DURABILITY REPORTRDenver Technical Service Center Civil Engineering Services Materials Engineering Research Laboratory Denver, Colorado*

- The paper exclamation has constructed 27 alternative canal-lining test sections to assess durability and effectiveness (seepage reduction) over severe rocky sub grades. The lining materials include combinations of geosynthetics, shortcrete, roller compacted concrete, grout-filled mattresses, soil, elastomeric coatings, and sprayed-in-place foam.
- The test sections are predominantly located in central Oregon, with one in Montana and one in Oklahoma. Each test section typically covers 15,000 to 30,000 square feet. The test sections now range in age from 6 months to 7½ years.
- Preliminary benefit/cost (B/C) ratios have been calculated based on initial construction costs, durability (service life), maintenance costs, and effectiveness (determined by full-scale preconstruction and post construction ponding tests).

Syed Hasan1, Gunvant Vaghela2, James Yip3, Ben Chung4, *SHOTCRETE DESIGN FOR IRRIGATION CANAL LINING*

- The major artery of Lake Wyangan irrigation system is the 16km long Lake View Branch Canal (LVBC) which was installed mainly in 1928. The 75mm thick reinforced concrete lining is currently in a poor condition withsignificant water loss through seepage and needs replacement as part of Lake Wyangan Modernization project.
- The main factors to be considered in the selection of a lining type include durability, seepage loss, construction cost and time, and maintenance cost. For irrigation canals, the use of concrete (cast in place or precast) with or without reinforcement is the most common practice of canal lining.
- A shortcrete lining (unreinforced or fiber reinforced) isuncommon for irrigation canals and there has been limited (if any) documentation of its recent usage in Australia. Atrial comprising approximately 27m long prototype (with fiber reinforced and unreinforced) shortcrete lining of differentjoint

configurations constructed on ground having similar properties to the LVBC was undertaken. On the basis of thetrial result together with cost and performance, unreinforced shortcrete lining with transverse and longitudinal controljoints was selected as the preferred canal lining option for un-obstructed flow of water without excessive seepage. Thispaper provides details of the LVBC renewal, including a literature review of irrigation canal lining, the development of design and the validation process.

SHIV KUMAR SHARMA, U. Tikekar *Improving Irrigation Efficiency: Lining of Canals, A Case Study of Rajasthan Feeder and Sirhind Feeder Canal, Central Water Commission, New Delhi*

- Lining of canals is an important method to improve efficiency in irrigation sector. A case study of lining of two parallel canals, Rajasthan Feeder (capacity 18500 cusecs) and Sirhind Feeder (capacity 5272 cusecs), off taking from Harike Headworks(Pb) is presented here. Various issues involved in the lining of such important canals carrying considerable discharge have been discussed.
- E.g. lining of canals having common bank, minimal closure time, Geo-synthetics etc. MoWR and CWC were required to device various design issues involved in the lining of

these two important canals. An expert team comprising designers and material testing personnel together with Project Officers worked out different alternatives and implementation strategies.

- Many important observations were made during the deliberations of this expert team which are of interest to the planners and designers of water conveyance systems, Main issues involved herein revolve around very short time available for repairs and introduction of Geo-synthetic material for lining. There may be similar situations elsewhere and experience gathered here may be of substantial assistance in other projects

Z. Iqbal, R.T. MacLean, B.D. Taylor, F.J. Hecker and D.R.*Bennett Seepage losses from irrigation canals in southern Alberta,Irrigation Branch, Alberta Agriculture, Food and Rural Development, Agriculture Centre, 100 - 5401 - 1 Avenue South, Lethbridge,Alberta, Canada T1J 4V6*

- A study was conducted to estimate seepage losses fromunlined irrigation canals in the 13 irrigation districts in southernAlberta. The ponding method for measuring the rate of seepage fromcanals was used to determine seepage losses at 29 sites in the irrigation districts. This method used poly-lined earth plugs at both ends of150 m long straight canal segments. These reaches were filled withwater to their operational depth, and the drop of water from full supplylevel to 80% of the design depth was recorded.
- Water levels wereadjusted for rainfall and evaporation with nearby weather-station dataand with pan evaporation data measured on-site. Seepage rates fromeach reach were grouped into one of three soil

textural classes: coarse,medium, or fine. Attempts were made to get a broad range of soils;however, most soils were in the medium textural class, by far thedominant soil texture group in southern Alberta.

MATERIALS

MATERIAL USED FOR LINING

The various materials are available for lining the canal section like concrete, Shortcrete, HDPE sheet, these are explained as below.

- Concrete: Excellent durability, but only 70 percent long-term effectiveness. Irrigation districts are familiar with concrete and can easily perform required maintenance
- Shortcrete: Shortcrete can be advantageously used as a lining material for canal lining
- Exposed HDPE - Excellent effectiveness (90 percent), but susceptible to mechanical damage from animal traffic, construction equipment. Also often difficult to maintain because of irrigation districts unfamiliarity with geomembrane materials, and need for special equipment to perform repairs.

METHODOLOGY

A. *Site selection*

In present study “KHADAKWASLA CANAL” right bank canal is selected; this canal is still under construction. Mainly this canal is unlined and red alluvial soil is found locally. Selected site is located on right bank canal of KHADAKWASLA CANAL of Khadakwasla dam. Length of canal is 60 km out of which 4 km section is selected. The bottom width and top width of channel is 6m and 8 m respectively. Seepage losses are more in unlined section. Some portion of a canal is lined. The main aim of the project is to find out the actual seepage losses from lined and unlined section of canal and compare it with theoretical losses; also suggest different materials which can reduce seepage losses up to maximum level and compare them.

B. *Data collection*

There were mainly two methods used to evaluate seepage losses of “KHADAKWASLA CANAL”

1. Direct measurement (Inflow-outflow method)
2. Empirical formulas

Direct measurement for seepage losses (Inflow-outflow method):

This method gives direct measurement of flow rate in to reach and out of reach of canal; so flow of rate which goes into the soil can be easily find out.

S = Qi + R – Qo – D + I – E

S = seepage through canal

Qi = upstream inflow

R = Rainfall

Qo = Downstream outflow

I = inflow along the reach

D = evaporation loss

E = outflow along the reach

Empirical Formulae for seepage evaluation

Empirical formulas were used to find out the seepage losses by theoretical means. These formulae were presented by Magdy H. Mowafy in Sixth International Water Technology Conference, IWTC 2001, Alexandria, Egypt to find outIsmailia Canal seepage losses in Egypt.

Mortiz Formula (USSR)[1]

$S = 0.2 * C * (Q/V)^{0.5}$

In which;

S = are the seepage losses in cubic foot per second per mile length of canal,

Q =I s the discharge (ft^3/sec), - 1054

V = is the mean velocity (ft/sec), - 1988

C = is a constant value depending on soil type taken as o.34 for clay and2.2 for sand soil. – 2.2 (FOR CLAY)

Therefore, S = 0.3203 m^3/sec / km

Molesworth and Yennidunia (Egypt)[1]

$S = C * L * P * R^{0.5}$

In which;

S = the conveyance losses for a given canal length (m^3/sec),

L= the canal length in km.= 4km

P = the wetted perimeter in m,= 10.50m

R = the hydraulic radius in m, = 0.489513m

C = the factor depends on soil types, for clay equal 0.0015 and forsand equal 0.003.

Therefor, S=0.0440 m^3/sec / km

Hungarian Formula[1]

S=1700*da*H*(b+H*So)

S = the seepage losses in m3/day/per meter length of canal;

da = the effective size diameter of the grains of the soil = 10

H = the water depth in canal = 0.86

B = the bottom width of canal = 5.73

So = the longitudinal bed slope 1:1.5

Therefor, S=0.963 m^3/sec /km

Remedies to reduce seepage losses

After evaluation of seepage losses by using direct measurement and empirical formulas, Different alternative lining materials are suggested and their benefit cost ratio are calculated to find out the best suited material for lining which will reduce seepage losses upto maximum extend.

Demo model

Demo model has been constructed of timber material. 3 canals system ofunlined, concrete lined,(HDPE+ concrete) lined are tested for getting clear idea about seepage losses in unlined, concrete lined,(HDPE+ concrete) lined canals.

Results and comparison

Data analysis is done by using direct measurement and empirical formulae. The Calculated results are compared by 1.Direct measurement 2.empirical formulae and best economical solution is obtained to reduce seepage losses.

Model making

DATA ANALYSIS

The collected Data of KHADAKWASL canal for 4 km section has been analyzed by direct measurement & Empirical formulas.

(MILE 0 TO 50)

Sr. No.	Structure or Nature of off take	Chainage Mile Number	Length in Feet	Hydraulic Gradient	Progressive Design Discharge in Cusecs	Bed Width in Feet	Side Slope	Value of "N"	F.S.D. in Feet	Area of Section in Sq. Feet	Wetted Perimeter in Feet	Hydraulic Mean Depth	Velocity in Feet per Sec.	Calculated Discharge in Cusecs	Proposed F.S.D. in Feet	C.B.L. Feet	Remarks
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Head Regulator	0/0	450	1 IN 5625	2050	18.58	1.5 : 1	0.02	13.60	530.12	67.61	7.84	3.91	2067	14.00	1882.[illegible] 1881.92	
	S.W.F	0/450	4158	1 IN 5400	2050	27.00	1.5 : 1	0.02	11.80	527.46	69.54	7.58	3.90	2097	14.00	1881.1[illegible]	
3		0/4608 (1/0)	2850	1 IN 7917	2050	28.00	1.5 : 1	0.02	13.00	617.50	74.87	8.24	3.39	2097	14.00	1880.79	
4		1/2850	2085	1 IN 6516	2050	27.00	1.5 : 1	0.02	12.80	571.87	72.08	7.93	3.63	2079	14.00	1880.55 1880.23	
5	Distributory No.1	1/4935 (1/5255) (2/0)	1170	1 IN 7312	2050	27.00	1.5 : 1	0.02	12.80	591.36	73.15	8.03	3.50	2069	14.00	1880.07	
6		2/850	1150	1 IN 7188	2050	24.00	1.5 : 1	0.02	13.30	584.53	71.95	8.12	3.54	2069	14.00	1879.91	
7		2/2000	2489	1 IN 9573	2050	27.00	1.5 : 1	0.02	13.70	651.43	76.39	8.52	3.16	2060	14.00	1879.65	0.31 Loss of [illegible] for Acquadu[illegible]
8	Aqueduct	2/4489	691	1 IN 7678	2050	27.00	1.5 : 1	0.02	13.00	604.50	73.81	8.18	3.44	2079	14.00	1879.34 1879.25	
9	Outlet No. 6	2/5180 (3/0)	4500	1 IN 7778	2050	27.00	1.5 : 1	0.02	13.00	604.50	73.81	8.18	3.42	2067	14.00	1878.67	
10	Outlet No. 7	3/4500 (3/5220) (4/0)	1202	1 IN 9246	2040	27.00	1.5 : 1	0.02	13.90	665.11	77.11	8.62	3.24	2160	14.00		

Measurement sheet of canal Discharge at KHADAKWASLA CANAL

Direct measurement (Readings):

The following table shows discharge and velocity of water flowing through NeeraDevdhar canal in summer 2024 by direct measurement method.For lined and unlined canal .

Table showing discharge and velocity

Chainage (m)	Breadth (m)	Water Depth (m)	Slope V:H	m*d	B+md	(AREA) (B+md)*d (m^2)	PERIMETER P=B+2d(√1+N^2) (m)	HYDRAULIC RADIUS R=A/P (m)	VELOCITY V= (m/s)	Discharge (m^3/s)
4608	5.73	0.86	1:1.5	0.4927	6.2227	5.315522	10.50	0.506240	0.605942	3.722165
4508	5.73	0.86	1:1.5	0.4927	6.2227	5.315522	10.50	0.506240	0.605942	3.722165
4408	5.73	0.86	1:1.5	0.4927	6.2227	5.315522	10.50	0.506240	0.605942	3.722165
4308	5.73	0.86	1:1.5	0.4927	6.2227	5.354016	10.50	0.506240	0.603954	3.722165
4208	5.73	0.86	1:1.5	0.49564	6.2256	5.354016	10.59	0.505572	0.603954	3.792195
4108	5.73	0.86	1:1.5	0.49564	6.2256	5.354016	10.59	0.505572	0.603954	3.792195
4008	5.73	0.86	1:1.5	0.49564	6.2256	5.354016	10.59	0.505572	0.603954	3.792195
4007	5.73	0.86	1:1.5	0.49564	6.2256	5.356516	10.59	0.505572	0.603954	3.792195
4006	5.73	0.86	1:1.5	0.49564	6.2256	5.35651	10.79	0.505572	0.603954	3.792195
4005	5.73	0.86	1:1.5	0.49564	6.2256	5.35651	10.79	0.505572	0.604716	3.792195
4004	5.73	0.86	1:1.5	0.49851	6.2285	5.35651	10.79	0.505572	0.604716	3.820539

4003	5.73	0.87	1:1.5	0.49851	6.2285	5.35651	10.79	0.505572	0.604716	3.820539
4002	5.73	0.87	1:1.5	0.49851	6.2285	5.35651	10.79	0.505572	0.604716	3.820539
4001	5.73	0.87	1:1.5	0.49851	6.2285	5.35651	10.79	0.505572	0.604716	3.820539
4000	5.73	0.87	1:1.5	0.49851	6.2285	5.35651	10.79	0.505572	0.604716	3.820539
3900	5.73	0.87	1:1.5	0.49851	6.2285	5.35651	10.79	0.505572	0.604716	3.820539
3800	5.73	0.87	1:1.5	0.49851	6.2285	5.35651	10.06	0.505572	0.606372	3.820539
3700	5.73	0.87	1:1.5	0.49851	6.2285	4.67625	10.06	0.505572	0.606372	3.820539
3600	5.73	0.87	1:1.5	0.4375	6.2393	4.67625	10.06	0.564239	0.606372	3.820539
3500	5	0.87	1:1.5	0.4375	5.4375	4.67625	10.06	0.564239	0.606372	3.821541
3400	5	0.87	1:1.5	0.4375	5.4375	4.67625	10.06	0.564239	0.606372	3.821541
3300	5	0.87	1:1.5	0.4375	5.4375	4.67625	10.06	0.564239	0.606372	3.821541
3200	5	0.875	1:1.5	0.4375	5.4375	4.67625	10.06	0.564239	0.606372	3.821541
3100	5	0.875	1:1.5	0.4375	5.4375	4.7872	10.213	0.564239	0.606372	3.821541
3000	5	0.875	1:1.5	0.44	5.4375	4.7872	10.213	0468735.	0.607232	3.821541
2900	5	0.88	1:1.5	0.44	5.44	4.816612	10.230	0.468735	0.607240	3.821541
2800	5	0.88	1.:1.5	0.4425	5.44	4.816612	10.230	0.467956	0.60850	3.841543
2700	5	0.805	1:1.5	0.4425	5.4422	4.816612	10.230	0.467956	0.608568	3.82301
2600	5	0.805	1:1.5	0.4425	5.4422	4.816612	10.230	0.467956	0.608568	3.82305
2500	5	0.805	1:1.5	0.4425	5.4422	4.816612	10.230	0.467956	0.608568	3.90441
2400	5	0.805	1:1.5	0.445	5.4422	4.816612	10.230	0.467956	0.609090	3.90441
2300	5	0.805	1:1.5	0.445	5.4422	4.816612	10.249	0.467956	0.609090	3.90441

2200	5	0.805	1:1.5	0.4475	5.4422	4.816612	10.249	0.467956	0.611043	3.90441
2100	5	0.805	1:1.5	0.4475	5.4422	4.96405	10.249	0.467956	0.611043	3.90441
2000	5	0.895	1:1.5	0.455	5.442	4.96405	10.274	0.471421	0.612034	3.90441
1900	5	0.91	1:1.5	0.455	5.4475	4.96405	10.274	0.471421	0.676216	3.90441
1800	5	0.91	1:1.5	0.455	5.4475	4.96405	10.27964	0.474288	0.676216	3.90441
1700	5	0.91	1:1.5	0.455	5.4475	4.96405	10.27964	0.474288	0.676216	4.00510 3
1600	5	0.91	1:1.5	0.455	5.4475	4.96405	10.27964	0.474288	0.676216	4.51995 6
1500	5	0.91	1:1.5	0.455	5.455	4.96405	10.27964	0.474288	0.676216	4.51995 6
1400	5	0.91	1:1.5	0.4575	5.455	4.96405	10.27964	0.474288	0.676216	4.51995 6
1300	5	0.91	1:1.5	0.4575	5.455	4.984462	10.27964	0.474288	0.678415	4.51995 6
1200	5	0.915	1:1.5	0.4575	5.455	4.984462	10.27964	0.474288	0.678415	4.51995 6
1100	5	0.915	1:1.5	0.4575	5.455	4.984462	10.27964	0.474288	0.678415	4.51995 6
1000	5	0.915	1:1.5	0.4575	5.455	4.984462	10.27964	0.481215	0.678415	4.56160 9
900	5	0.915	1:1.5	0.4575	5.4475	4.984462	10.31568	0.481215	0.678415	4.56160 9
800	5	0.915	1:1.5	0.46	5.4475	4.984462	10..31568	0.481213	0.678415	4.56160 9
700	5	0.915	1:1.5	0.46	5.4475	4.984462	10.26162	0.481213	0.678415	4.56160 9
600	5	0.92	1:1.5	0.46	5.4475	5.0232	10.31568	0.481213	0.678415	4.56160 9
500	5	0.92	1:1.5	0.46	5.4475	5.0232	10.31568	0.481213	0.68140	4.56160 9
400	5	0.905	1:1.5	0.425	5.4475	4.934125	10.31568	0.482930	0.68140	4.90160 9
300	5	0.91	1:1.5	0.455	5.46	5.0232	10.31568	0.390008	0.672015	5.15450
400	5	0.905	1:1.5	0.425	5.4475	4.934125	10.31568	0.482930	0.68140	4.90160 9
300	5	0.91	1:1.5	0.455	5.46	5.0232	10.31568	0.390008	0.672015	5.15450
200	5	0.92	1:1.5	0.46	5.46	5.0232	10.31568	0.390008	0.752240	5.15450

The Data analysis is as follows,

Direct measurement calculation:

Discharge and seepage losses

Discharge	on zero chainage	on 4000 chainage	Difference
	3.72 m3/s	5.15 m3/s	1.43 m3/s
No. of Distributaries in 7 km channel	9		
Discharge of each distributaries	50 liter/sec		
Total Discharge	9*50=450liter/sec =(0.45 m3/sec)		
Total reduction in discharge	0.45-0 = 0.4 m^3/s		
Seepage loss	Seepage loss = loss in discharge - evaporation loss		
	= 0.45(m^3/s)- 0.01(m^3/s)		
	= 0.98 (m^3/s) in 4000 meters		

- 999 liter/sec water can be saved in 4000 meter run by applying HDPE sheets (high densilepolytherin sheets) and providing cement concrete cover to protect HDPE sheets from any action or attack.
- Cement Concrete lining cost for "KHADAKWASLA" canal project is 1.5 crore/kilometer
- For example: we considered 4 km channel section.

Cost and calculations for (concrete and HDPE) lining

Material	Cost	TOTAL Quantity	Cost for 4 km canal section
Cement Concrete lining	2200 crore/kilometer (as per tender value of KHADAKWASLA canal lining)	2200crore/km * 4 KM	8,80,00,00
HDPE sheet	185 RS/square meter	185 * 189840 sq meter	3,51,20,400
Cement Concrete + HDPE sheet lining	8,80,00,00+3,51,20,400	8,80,00,00+ 3,51,20,400	4,39,20,400
HDPE sheets (with geotextile cover)	185*189840sq meter *2	7,02,40,800	7,02,40,800
Cement Concrete + HDPE sheet+ geotextile cover lining	8,80,00,00+ 3,51,20,400+ 7,02,40,800=	21,03,61,200	11,41,61,200

- By using HDPE sheets we can save 999 liter/sec water for this KHADAKWASLA right bank canal (4 km section)
- By assuming 0.49m^3/s as a discharge which can be saved in seepage losses
- For bottom width side area is = (5+2)*4000 = 28000 sq meter
- For side channel area is = (5.73 + 2)*4000 = 30920 sq meter
- For side channel area is = (5.73 + 2)*4000=30920 sq meter
- Total area is = 28000 + 30920 +30920 =89840 sq meter (4)
- Volume of water saved by using HDPE sheet =999liter/ = 249.75 liter/sec/km

  = 0.249 m^3/sec/km
- For 4 km we saved 0.999 liter/sec
- Consider this as a discharge and used for Rice crop and Wheat Crop,

Benefits due to lining for RICE and WHEAT crop per year

Parameter	Rice Crop		Wheat Crop	
Basic Period	100 Days		100 Days	
Duty	(864*100)/(120)	720 ha/cumec	(864*100/50)	1728 ha/cumec
Assuming saved Discharge by HDPE sheet for 7 km	0.44 m^3/sec			
Area = (discharge*duty)	0.98 * 720	31.68 hactare	0.98 * 1728	760.32 hectare
Production	4 ton/hectare		3 tons /hectare	
	352.8*4000	14,11200 kg Rice	846.72*3000	25,40160kg wheat
Approx wholesale rate	25 Rs/ kg		20 Rs/ kg	
Total earning	25 * 14,11,200	31680000 RS	20*25,40,160	45619200 Rs
Benefits due to lining	31680000 + 45619200 = 77299200 Rs			

Empirical formula for seepage losses:

Seepage losses by empirical formulas

Formulas	Mortiz Formula	Moles worth &Yemidunia	Hungarian Formula
SEEPAGE	0.3203 m^3/s/km	0.0440 m^3/s/km	0.9634 m^3/s/km

RESULTS & DISCUSSION

RESULTS:

The seepage losses by different Empirical formulas and by direct measurement method are calculated. The benefit cost ratios by using different material are calculated. Both results are represented as follows.

Seepage loss calculation

DIFFERENT METHODS	Mortiz Formula $m^3/s/km$	Moles worth &Yemidunia $m^3/s/km$	Hungarian Formula $m^3/s/km$	Direct Measurement $m^3/s/km$
SEEPAGE	0.3203	0.044	0.249	0.9634

Benefit cost ratio

1. SR. NO	MATERIAL	BENEFIT COST RATIO
1	HDPE + CONCRETE	10.12
2	HDPE + SHORTCRETE	5.33
3	IITD + CONCRETE	7.34
4	IITD + SHORTCRETE	6.080
5	HDPE(with geotextile cover) + CONCRETE	7.095
6	HDPE (with geotextile cover) + SHORTCRETE	9.40

As per results shown in table(6.2) B/C ratio of all the lining materials which are shown above are more than 1.So all the materials can be used for canal lining and gives benefits.In today's condition IITD sheets are not easily available in market; So HDPE sheet is a best solution to minimize the seepage losses of concrete lined canal

Results of Demo model Testing

Size of model = Top width = 18 centimeter

Bottom width = 7 centimeter

Depth of water = 4 centimeter

The 1.5 liter volume of water was used to check seepage losses in

1) Unlined canal

2) Concrete canal

3) (HDPE + concrete) canal.

Seepage losses in Demo model

Sr. No.	Type of canal	Seepage losses time after 15 min		Average Valve	Seepage losses time after 1 Hr		Average Valve	Retain water	
		Test 1	Test 2		Test 1	Test 2		After 15 min	After 1 Hour
1	Unlined	1.1 liter	1 liter	1.05 liter	1.5 liter	1.5 liter	1.5 liter	0.45 liter	0 liter
2	Concrete	0.5 liter	0.55 liter	0.525 liter	1.2 liter	1.25 liter	1.225 liter	0.975 liter	0.275 liter
3	HDPE+Concrete	0 liter	0 liter	0 liter	0 liter	0 liter	0 liter	1.5 liter	1.5 liter

Model making

(1.unlined canal, 2.concrete canal, 3.HDPE + concrete canal)

CONCLUSION

- The benefit cost ratio is greater than 1. This method of HDPE sheets lining justifying its application, further we can lined different irrigation channel using this lining material and reduces the seepage loss .It will help in increasing production and overall benefit
- HDPE sheets are advantageously used for canal lining and also useful for reducing the Result of losses in unlined as well lined canal also.HDPE sheets reduces the losses upto 99% if fixed and maintained properly.
- (HDPE + CONCRETE) lining Material affect less due to different actions

FUTURE SCOPE:

- HDPE sheets and other geomembrane materials are good option to reduce seepage losses in canal. Advanced search can be done on lining materials which will reduce cost as well as seepage losses up to 100 %
- RADAR, SHAFT ENCODER,BUBBLER SYSTEM will be best options to find out discharge of canal at different sections as well as seepage losses. Advancement in sensor system can be done to reduce the seepage losses
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