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Minimize Seepage Loss Through Canal Slope and Bed by Reducing Permeability of Soil with Lime Admixture

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Abstract:
As per IS 10430 (2000): the canal reaches sufficient length having a permeability of 10^{-6} cm/s or less and doesn't need to line when the velocity in the channel does not exceed the permissible rate. Co-efficient of permeability 1×10^{-6} cm/sec is the optimum value above which canal lining is required. Canal lining is a very costly activity. Admixture in embankment soil will decrease the Coefficient of permeability, and as per the code, the lining does not require. Lime is a very cheap, easy, and widely available admixture. Lime also works as a binding material. Experimentally, based on the primary parameter, we may obtain the quantity of lime to reduce permeability which will use to avoid lining in the canal. The sample was collected from three places in the Indira canal and mixed with a 3.60% optimum quantity of lime. A 0.7×10^{-6}cm/sec permeability coefficient has been evaluated below, and canal lining is not required.

1. Introduction

Canals, artificial waterways, are used to transport water for irrigation and other human uses. Water loss occurs in channels due to seepage, evaporation, breach of canals, flood excess water, and holes made by rats, animals, and insects. Evaporation and seepage loss are very high and account for between 25% to 50% of diverted water in canals. The evaporation loss accounts for nearly 2-3%, less than seepage loss and dependent on temperature, humidity, wind velocity, and the season. The seepage loss occurs either through percolation or absorption. In percolation loss, the water loss through a continuous zone formed between the canal and the water table. This zone contains fully saturated soil, which establishes a continuity of flow of water lost from the canal and joins the groundwater reservoir. In Absorption Loss, there exists a zone of saturated soil below the channels accompanied by a zone of soil with decreasing saturation, which in turn is bounded by a soil site saturated by the capillary action of water rising from the adjacent water table level. There are many methods used to reduce seepage loss in the canal. Seepage losses occur through its bed and sides.

1.1 Necessity:

- To minimize the seepage loss through the bedsides of the canal.
- To prevent scouring and erosion of the bed and sides of the canal due to heavy rainfall causing high-velocity flood water.
- To increase the flow velocity, thus discharge in the canal section is increased to increase the flow velocity.
- To prevent waterlogging of the area due to the rise in the water table. Seepage losses occur through its bed and sides.
- Canal lining on the inner side of the embankment and bed of the canal.

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- Soil modification by adding admixture in the soil of the embankment.

The objective of this research aims to minimize seepage loss through the canal embankment by reducing the permeability of soil with lime ad mixture to make the embankment more impervious in the canal system of District Lucknow.

The following are the objectives to suggest :

- Sustainable soil of canals
- Modified soil with lime channels for economical construction.
- Sustainable design of canal embankment.

1.2 Uses of Modification:

Canals must be constructed and designed to handle extremely high water pressure. Additionally, they must be able to offer protection against the risk of erosion brought on by flowing water and must be watertight so they will not leak.

When soil fragments separate at the seepage exit or seepage discharge face of inter granule seepage, backward erosion piping occurs (water seeping through pores of dirt). Internal erosion happens when soil particles become mobile due to high flow rates. Formation of a concentrated (big) leak that could result in excessive water loss or eventually damaged canal prevented by reducing permeability by modified soil.

Objectives of modified soil of embankment:

1. To control and direct the flow of seepage water through a hydraulic structure
2. To prevent movement of soil particles from or from various zones and canal bed
3. To avoid failure of the embankment of the canal.
4. To prevent the development of concentrated leakage.
5. To develop a safe cross-section that can construct from materials available to the site at minimum construction and maintenance costs.
6. To prevent internal erosion occurs when soil particles become mobile due to excessive flow rates.

1.3. Effect of water on Soils

Soils are composed of single particles. The load's transfer at the particle contacts with regular and shear forces. The maximum shear force which can share at the particle contact is proportional to the effective normal force at the connection, as defined by the total inter-particle force and the pore water pressure, should the soil be saturated. The pore water pressures can correspond to the (a) hydrostatic head, should the soil skeleton be submerged, or (b) to an excess pressure that exceeds the hydro static head.

1.4 Method of Construction:

Canals are designed and built to withstand enormous water pressure. In addition, they have to be watertight so that they will not leak, and they have to be able to offer protection from the risk of erosion caused by the flowing water.

The bottom of the canal is leveled off and compacted. A filter layer consisting of sand and gravel are put in place, and a sealing layer of fine soil, cement lime, or asphalt is. There is always a certain amount of leakage through the sealant and the filter ensures that the sealant does not get washed away. If fine soil uses as the sealing layer, it must cover by an erosion-resistant layer. The various layers must be correctly compacted to avoid cracks in the sealing layer.Ifnot controlled, it can develop concentrated leaks that can lead to severe consequences and, in extreme cases, failure of an embankment.

Modified soil of the canal's embankment can also prevent waterlogging around low-lying areas of the channel.

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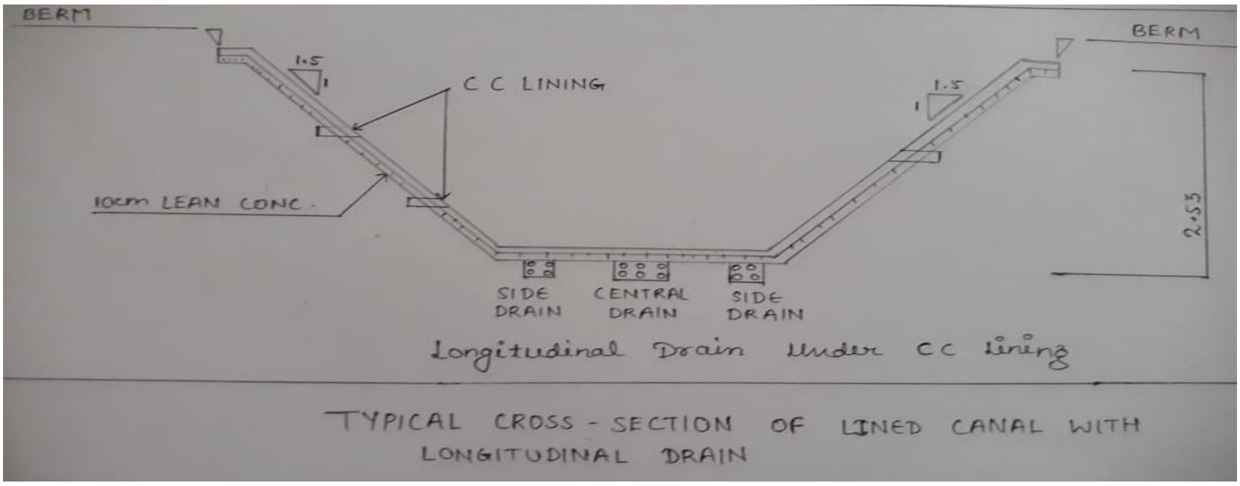
By making a canal less porous, the water velocity increases resulting in a more significant overall discharge. Increased velocity also reduces the amount of evaporation and silting that occurs, making the canal more efficient.
Indo Gangetic Plateau primarily has alluvial soil with a variety of properties. Much research has been done on this topic, but a research paper focuses on a few significant issues, like the modified soil of embankment.
Side embankments of the canal will be protected and made impervious by lime modification of soil which may be economical also.

1.5. Advantages Of Modified Soil of Embankment:

- Reduction in losses due to seepage:
  The lining prevents dripping and, in the end, can irrigate more water with the same amount of water, and can save valuable water.
- Prevention of waterlogging:
  Seepage is the leading cause of waterlogging. If the canal lines, the seepage is reduced, thus helping protect it from waterlogging.
- Low maintenance cost: The maintenance of lined canals is less than the Prevention of weed growth. The lining prevents the growth of weeds.
- Stepper bed slope: The impervious embankment can maintain high velocity, providing the stepper bed slope.
- Less permeable: water speed will increase, leading to more significant overall discharge.



To protect canal beds against erosion and to prevent seepage from the bottom or side of a canal, may use impermeable soil.

2. Literature Review

Mannal On Canal Lining (Revised) Dated 29/2000, Indian National Committee On Irrigation And Drainage, Mowr, Govt Of India

Canals, artificial waterways, are used to transport water for irrigation and other human uses.Modified soil is provided in the channel's embankment to resist water flow through its bed and sides. Modified soil reduces seepage loss of irrigation water by adding an impermeable layer for the bed and sides of the canal to improve the life and discharge capacity of the channel.

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Lime As Modifier:
The objective of this research is to improve the soil of the embankment by adding lime to make the embankment more impervious, i.e., to reduce the permeability of the earth to minimize seepage loss in the canal system. Lime is a cheaper material,widely available in abundance. So, lime has been taken as an additive to reduce permeability and to make more impervious embankments.
3.2. Soil
- Samples: This provides by taking soil samples at appropriate locations.
- Suitability: Clayey soils, including heavy clays, moorums, and other soils met within the alluvial plains, can be effectively treated with lime.

3.3. Lime
- Type of lime: Lime for lime-soil stabilization work shall be calcitic dry lime, commercially available, slaked at the site, or pre-slaked lime delivered in suitable packing.
- Purity: The purity of lime affects the strength of lime soil stabilization. The effectiveness of lime in its reaction with clay minerals is dependent to a reasonable extent on its chemical composition, i.e., the amount of calcium oxide in the lime. The purity of lime expresses as the percentage of calcium oxide in the lime. It is
- , generally recommended that lime used for soil stabilization should have a purity of 50 percent.
- Fineness: For effective stabilization with lime, uniform mixing is a pre-requisite, and the degree of mixing depends on the fineness of lime

2.2. **Evaluation Of Lime Requirement**
- A small addition of lime in clayey soil increases the workability of the soil, possibly due to base exchange, flocculation phenomenon, or a combination of the two. As the dose of lime increases, the strength of the mixture increases. It suggests that the lime added initially in small dosages is utilized to satisfy the affinity of the soil for lime. The quantity of lime needed to fulfill this affinity terms the lime fixation point or lime retention point. Lime required for this purpose is usually 1 to 3 percent.

2.3. **Moisture Absorption Method**
Capillary absorption of water is an intrinsic property of every soil. Besides other factors, this depends mainly on the mineralogical composition and particle size distribution.
2.3.1. If the strength values of the soil-lime mix obtained at optimum lime content are much more than those required from design consideration, strength tests may be conducted with reduced lime content to fix the design mix. However, in no case should the lime content be less than the minimum value of lime required for durability
2.3.2. Degree of Pulverization
2.3.3. For effective stabilization, the soil must be well-pulverized before adding lime. Yet, it may not be economical to pulverize heavy clays like black cotton soil to an appreciable degree.

3. **Construction Operations**
3.1. Pulverization and Mixing
3.1.1.can benefit from lime stabilization if the lime added to the soil is thoroughly mixed. The compacted thickness of the soil-lime layer or lift shall be in the range of 75-200 mm, depending on the efficiency of mixing and laying equipment.
. 3.2 Mix-in-place method

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The mix-in-place method permits rapid construction with a small labor force and relatively low cost. The equipment required is simple, and a large daily output can maintain. Its disadvantages are the difficulty of obtaining uniformity of mix and the difficulty of ensuring a uniform thickness of the processed soil. In the mix-in-place method, the following operations are involved:
(a) Pulverization of soil
(b) Spreading lime
(c) Mixing
(d) Addition of water
(e) Final grading
(f) Compaction, and
(g) Curing
3.2.1. Manual mixing: The manual method is more labor intensive, but because of its limitations in pulverizing and mixing, it should use for small jobs only.

3.3. Addition Of Lime

Lime may add to the prepared material in slurry form or a dry state. The moisture content shall equal the optimum moisture content and shall not exceed OMC by more than 2.0 percent.
3.3.1 Time Between Mixing and Compaction
3.3.2. Time interval between the mixing of lime and soil, and the compaction of the mix, has a definite effect on the gain achieved in strength.
3.3.3 Compaction
Immediately after spreading, grading, and leveling the mixed material, compaction shall carry out with an 8-10 tons smooth wheel roller or vibratory roller.
3.3.4. Curing
The duration of the curing period and the temperature at which curing takes place have a significant influence on the strength achieved. The normal curing period varies from 7 to 28 days at normal temperatures under wet conditions.

3.4. Soil-Lime Stabilization

Soil-lime uses as a modifier and a binder for high-plasticity soil. In addition to this, the lime can use the lime for the binding of granular soils also. The basic principle associated with soil-lime stabilization involves pozzolanic action. The pozzolanic reaction occurs due to the addition of hydrated lime with moist clay. It defines as, Hydrated lime ($Ca(OH)_2$ with pH>12) + Water (H_2O) + Clay (with SiO_2, Al_2O_3, and others) = Cementitious material with stable silicate hydrates and calcium aluminate hydrates.
The effects due to the addition of lime are an improvement in workability (slightly higher OMC as compared to the soil without lime), an increase in all types of strength-related properties by decreasing P.I., swell reduction, and earth becoming hydrophobic.
Lime is best suited for clayey soils (classified as S.C., ML, MH, CL, C.H. A suitable quantity of fly ash may add to gravel, sand, and silts.
• The Lime-Soil stabilization is suitable when >15% fines pass 425-micron sieve, and P.I.> 10
• There should include a minimum amount of lime in the soil to raise the pH level to 12.4. The remaining criteria of design are applicable after meeting this criterion.
• Air temperature >10°C, in shade purity of lime > 98% (by ASTM D 6276)
• OMC can determine by the Standard Procter test; Compaction > 98%
3.5 The subgrade may be of the following types:

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Free draining - Soil comprising gravel with sand or sandy soil having a permeability more significant than 10^{-4}cm/sec, that is, K >10^{-4} cm/sec.
Poor draining - Soil comprising fine sand, an admixture of sand, silt, and clay or soil having permeability between 10^{-4} cm/sec and 10^{-6} cm/sec, that is, 10^{-6}cm/sec< K <10^{-4}cm/sec.
Practically impervious - Soil comprising homogeneous clays with permeability less than 10^{-6}cm/sec, K <10^{-6} cm/sec.

3.5.1 Seepage Control

3.5.1.1 Seepage Control The seepage control. It mainly depends on the soundness and impermeability of the lining. Seepage losses also rely on the soil's nature and permeability of the soil, the depth of water in the canal, and the position of the subsoil water table below the bed level. The permissible seepage losses depend on the local conditions, such as the value of water and any likely damage to land and other property by water loggings, etc

Generally, the canal reaches sufficient length having permeability of 1 x 10^{-6} cm/s or less need not line when the velocity in the channel does not exceed the permissible rate.

3.5.2 Prevention of Water Logging There is an increase in groundwater level if the canals remain unlined. This condition, if unchecked, brings alkali salt to the surface, rendering land unfit for two cultivation. The lining of canals reduces the seepage appreciably and thus prevents water logging conditions.

3.5.3 Reduction in Cross-Sectional Area With improved canal efficiency due to the lining and higher velocity, reduced areas of the cross-section area are required to pass the same discharge. Consequently, there is a significant saving in the cost of land acquisition and canal structures.

3.5.4 Low Operation and Maintenance Cost Unlined canals require considerably increased operation and maintenance costs for periodic removal of silt, minor repairs, and removal of weeds and water plants. The provision of lining reduces these costs considerably.

4. Data Collection:

Soil samples had collected from the embankment at three places of Indira Canal in Lucknow District i.e.

1. Near Mati
2. Near Ayodhya Road Crossing
3. After Aquaduct

Laboratory Works:

We are finding primary Parameters, i.e., Sieve Analysis,Liquid Limit, Plastic Limit, OMC, dry density, and soil permeability.

I. Sieve Analysis

SN	SIEVE SIZE (mm)	SAMPLE-1(%FINER)	SAMPLE-2(%FINER)	SAMPLE-3(%FINER)	Selected Grading
1.	4.75	100	100	100	100
2.	2.00	98	97	98	97
3.	0.425	84	87	88	87
4.	0.075	33	38	41	38
5.	0.002	3	4	3	4

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II. Liquid Limit, Plastic Limit, Omc, Dry Density

SN	LL	PL	OMC	DRY DENSITY	Selected Parameter
SAMPLE-1	23	19	14.50	1.60	Sample -1
SAMPLE-2	24	20	15.00	1.55	
SAMPLE-3	24	20	16.00	1.57	

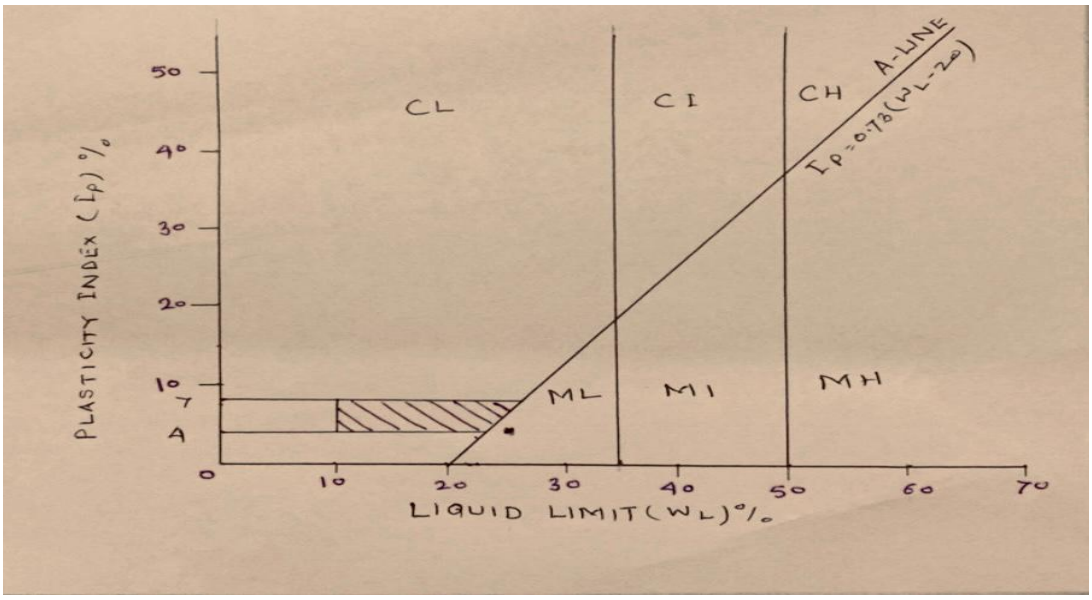
III.Permeability: Selected Sample

SN	Admixture	Test-1	Test-2	Test-3	Drysample condition	
1	Natural Soil	6.9×10^{-3}	6.4×10^{-3}	6.2×10^{-3}	crackles	
2	0.50	0.5×10^{-3}	0.4×10^{-3}	0.7×10^{-3}	crackles	
3	1.00	9.9×10^{-4}	9.3×10^{-4}	9.5×10^{-4}	crackles	
4	2.00	1.7×10^{-4}	1.2×10^{-4}	1.3×10^{-4}	crackles	
5	3.00	4.6×10^{-5}	4.4×10^{-5}	4.2×10^{-5}	crackles	
6	3.20	5.2×10^{-6}	4.9×10^{-6}	4.7×10^{-6}	crackles	
7	3.40	1.3×10^{-6}	1.4×10^{-6}	1.3×10^{-6}	crackles	
8	**3.60**	$\mathbf{0.8\times 10^{-6}}$	$\mathbf{0.4\times 10^{-6}}$	$\mathbf{0.9\times 10^{-6}}$	**crackles**	
9	3.80	0.9×10^{-7}	0.6×10^{-7}	0.5×10^{-7}	Fine crack	
10	4.00	0.9×10^{-7}	0.6×10^{-7}	0.5×10^{-7}	Fine crack	

5. Analysis

1. Soil of embankment has higherfine sand and silt content.
2. Indian Standard Classification System(ISC) had prepared to classify the soil by plasticity chart:

i. WL =2, PL=19
ii. PI = 23-19=4



Soil is ML

The Coefficient of natural soil permeability of natural soil was 6.5×10^{-3}cm/sec. As per IS 10430 (2000): Canals and Cross Drainage Works], the canal reaches of sufficient length having a permeability of 1x 10.6 cm/s or less need not line when the velocity in the channel does not exceed the permissible rate.The lining of the canal is very costly to work. Instead of canal lining,it may modify embankment soil to decrease the Coefficient of permeability. There are many materials available for the modification of the earth. Lime is the cheapest and most widely available material by which it could improve the soil. Adding lime to the ground will increase the workability and plasticity of the earth.Soil may crack when the soil dries, which causes the embankment failure. Tests were carried out to optimize lime content. Adding 3.6% lime is the optimum quantity above which crack may develop in the soil, and loss may happen in the embankment when it dries. 3.60% lime, the Coefficient of permeability was found out 0.7×10^{-6}cm/sec, and the crack was not developed in the soil when dried. Below the 0.7×10^{-6}cm/sec coefficient of permeability, the lining of the canal is necessary.

6. CONCLUSION:

The Coefficient of permeability 1×10^{-6}cm/sec is optimum above which lining of the canal is required. Canal lining is a very costly activity. Admixture in embankment soil will decrease the Coefficient of permeability, and as per the code, requirement lining of the lining is not required. Lime is a very cheap and readily and widely available admixture. Lime also works as a binding material. Experimentally, based on the primary parameter, the quantity of lime may be obtained, which will use to avoid lining in the canal. Received the sample from three places in the Indira canal, a 3.60% optimum quantity of lime was obtained, and a 0.7×10^{-6}cm/sec coefficient of permeability was found below which lining is not required; the lining of the canal is necessary.

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