WATER PROOFING
OF FIELD IRRIGATION CHANNELS IN
DESERT SOILS

By

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FOREWORD

In arid and semi-arid areas, crop productivity is generally limited by water availability for crops. Water availability for crops is dependent on the efficiency of irrigation systems. Farmers depend upon open earthen channels for carrying water to the fields. Impounding and conveying of water is costly and therefore it is necessary to ensure that the transportation of water to the land is done without much losses. Also excessive seepage of water from the field channels may create problems of water logging, which is happening at present in the Rajasthan canal area. Measures and strategies are reqired to efficiently control seepage losses in field channels and to increase the crop production.

Practical recommendations for the control of seepage losses using various indigenous materials have been evolved at CAZRI and the same have been summarised in this poublication. It is hoped that this monograph will serve the needs of the agricultural sector in arid regions.

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PREFACE

In peace or war the strength of a nation and the welfare of its people are dependent upon its natural resources. If the nation is to remain strong, these resources must be protected and developed.

Development of arid and semi-arid regions of the country cannot be achieved without the development of water. If we are to ensure sufficient food for future needs, it is of primary importance to conserve our land and water resources. Though arid land has sufficient arable land and plenty of good water, the source of this water is often far from the land to be cultivated.

Farmers depend upon open earthen channels for carrying water to the field. As the impounding and leading of water is costly it is necessary to ensure that the transportation of water to the land is done without much losses. It is, therefor, necessary to evolve a strategy which should effectively control seepage losses in field channels so that more area could be put under cropping.

In this monograph an attempt has been made to briefly present the different techniques adopted and to arrive at a suitable material for the control of seepage losses in irrigation channels. It is hoped that the monograph and the contained information will be useful for farmers in India in general and in arid zone in particular.

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INTRODUCTION

Need for conserving water

Development of arid and semi-arid regions of the country can not be achieved without the development of water resources if we are to ensure sufficient food for future needs, it is of primary importance to conserve our land and water resources.

Though arid region has sufficient arable land and plenty of good water, the source of the water is often far from the land to be cultivated. Unlined ditches are the most common means of conveying irrigation water from its source to the field.

Farmers depend upon open earthen channels for conveying water to the field. As the impounding and leading of water is costly it is necessary to ensure that the transport of water to the land is done without undue losses.

Looking to the vital problems of common farmer, a small study at the central research farm of the Central Arid Zone Research Institute investigating the efficiency of different indigenous materials in controlling the percolation losses in field irrigation channels was undertaken by the Hydrology section. Investigations were carried out on different materials and tests were conducted on field channels raised on small embankments. The suitablity and cheapness of the material in desert soils were examined and recommended for the application in large scale for field irrigation channels.

JUSTIFICATION FOR LINING

Water is the basic need for both domestic use and irrigation of crops. In Western Rajasthan the rainfall is low and erratic in distribution, with the result that the surface supplies are not adequate and also not dependable. The water supply, therefore, mostly depends on groundwater pumped from dug wells and deep tube-wells. In many regions, the ground water is lifted from deep wells either by pump or persian wheels which results in relatively high cost of irrigation. The irrigation water is, therefore, costly in adition to being inadequate which calls for the judicious utilisation including reduction of percolation losses, which may solve other problems caused due to water seepage.

Water is generally carried to cultivated fields by open field channels either dug in the fields or prepared in the raised embankments. It has been observed that quite a large amount of water is lost through seepage because of porous nature of soil. In this region it has been observed that the water from wells is carried to the fields by open channels of length of $\frac{1}{2}$ km or more. Consequently more than 40% more area can be developed with the same supply of water, if suitable techniques are evolved for lining of these earthen channels. The fourth irrigation practice seminar (1962) recommended that intensive field research should be taken on the economic and efficient method of conveying water to the fields. To save water from percolation to ground means to increase the duty (area irrigated per cusec of water), lining of these channels would be proper answer particularly in sandy areas. The loss of water through seepage creates many problems. One of them is loss of valuable water and the second serious problem of water logging. The salinity increases in the soil is due to evaporation from shallow water table. This causes deterioration of valuable agricultural lands. The lining of field channels have manifold objectives:

1. To increase the duty.
2. To prevent deterioration of agricultural land.
3. To increase the discharge.
4. To reduce recurring cost of maintenance.

Keeping the above facts in view and in order to increase the efficiency of irrigation, field tests were conducted at CAZRI.

SOILS

Soils are typical of the arid climate i.e. sandy, coarse textured, deep calcareous with lime concretion zone below. They are light textured and poor in structural development. In general they have high infiltration and permeability rates. (Kolarkar, A. S.) Soil Scientist of this Institute, has established the series of this region as a Pal series with the following characteristics. These soils of flat to gently sloping older alluvial plains have brown to reddish brown surface, loamy sand to sandy loam sub-soil followed by a weakly developed carbonate concretionary layer mixed with gravels at depth mostly of 80 to 120 cm. The subsoil is often more reddish, non calcareous. Surface is often loamy sand and upon ploughing forms clods which gives them some resistance to wind erosion. Morphological characteristics of the series is given below:

Trial site description

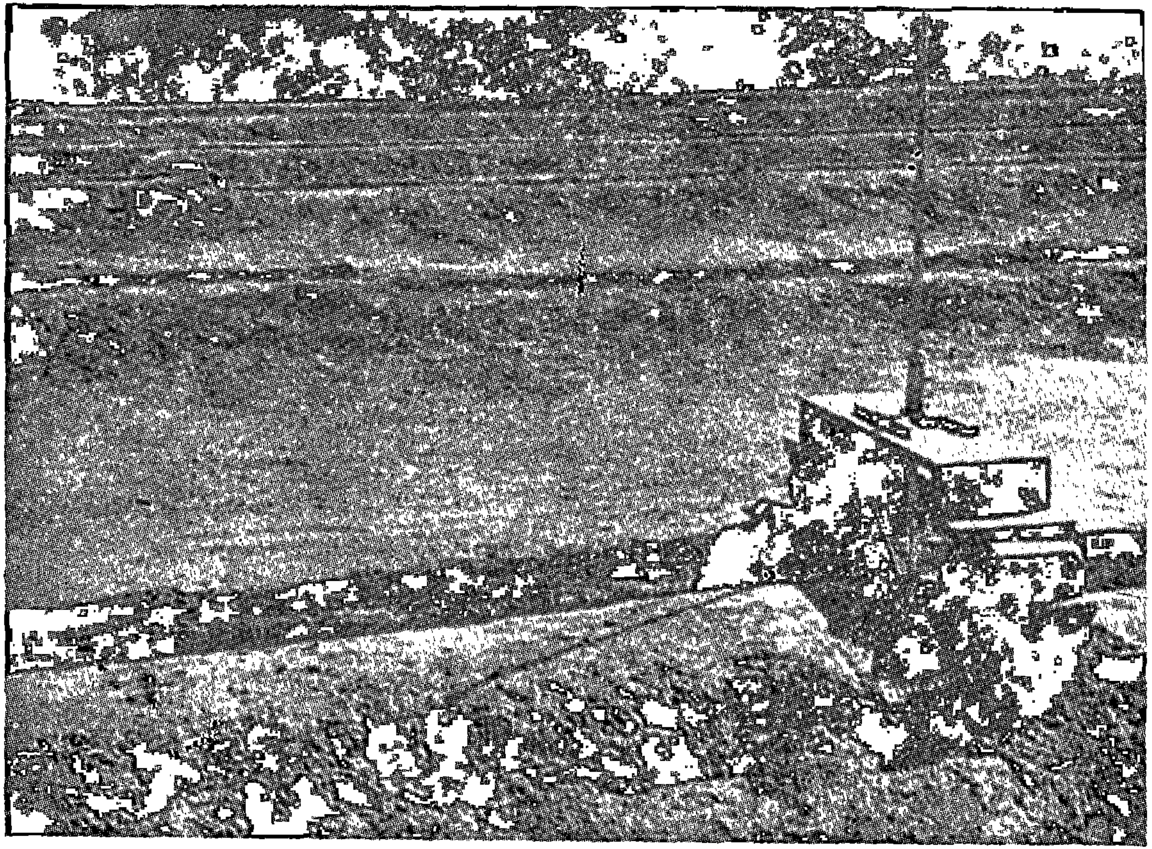
The soil series established is typical of this region with the following profile.

Centimetre

0-30 Reddish brown to dark reddish brown, loamy sand, very weakly developed, fine, subangular blocky to fine granular.

30-75 Reddish brown sandy loam fine dry, slightly hard, moist friable.

75-90 Light, reddish brown, somewhat compact zone with lime coated gravels.



General layout of unlined field experimental channels.

Particle size distribution of 0-80 cm horizon

Depth zone (cm)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)
0-30	28.5	56.9	5.6	8.6
30-75	24.9	51.2	13.0	10.5
75-80	40.0	39.9	5.4	14.4

Texture in the surface ranges from sandy to loamy sand with clay content of 6 to 9% and silt from 4 to 7%. The subsoil is brown to reddish brown, loamy sand to sandy loam with clay content of 8 to 12% and silt from 6 to 14%.

DESIGN OF FIELD CHANNELS

Field channels of parabolic shape of 0.45 sq. metre cross sectional area and of length 30 metres with bed slope of 0.5 to 1% on raised embankment (Fig. 1) were adopted for field trials. The channel section has been designed to carry a discharge of about 12.75 lit/sec at a maximum depth of flow of 15 cm.

As this section is generally adopted in the farmer's field to carry a discharge of about 9 to 13.5 lit per sec; the same section is adopted here for field testing.

ESTIMATION OF SEEPAGE LOSS (METHODOLOGY)

1. *Ponding method*

The test was conducted under ponding condition. Water is ponded between two damed sections of the channel and depletion of water level, in the section under test in particular time interval is measured. The seepage loss worked out from the recorded change in water level during the time interval. Water level changes

DESIGN OF FIELD CHANNELS
(CROSS SECTION AFTER LINING)

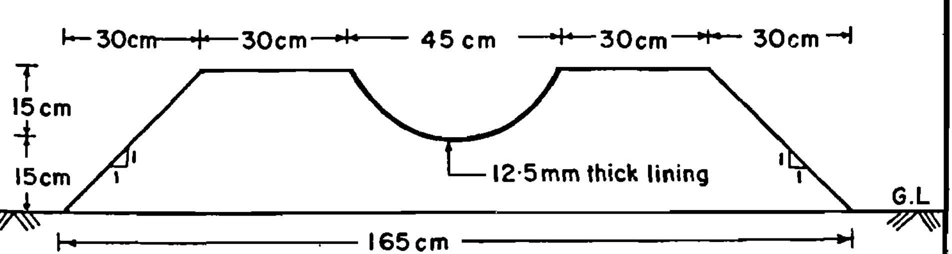


FIG-1

in different time periods were recorded and average water level fall due to seepage worked out. In the constant head method the water level in the section is maintained at one desired level. Frequent addition of water externally to maintain the constant head determines the seepage loss during the particular time interval, as the evaporation loss is negligible.

Recorded data showed that seepage loss measured by this method is greater than in inflow and outflow method. This may be due to ponding of water in the channel. Generally seepage loss is less in flow condition.

2. *Inflow and outflow method*

The quantity of water flowing into and out of channel between two sections, was measured. The difference between the two flow rates at inlet and out let determines the seepage loss. Evaporation loss during the trial tests is ignored since it is very small.

Instrumentation

1. 90°-V notches ($\theta = 90°$)
2. Point gauges.
3. Clock for recording time interval.

Calculation

Discharge equation adopted

$Q = 8/15 \; Cd \sqrt{2g} \tan \theta/2. \; H^{5/2}$

θ = angle of the 'V' notch.

H = Head of water above the tip of the V-notch.

This equation for working out discharge is valid for the type of V-notches adopted in the test. The type of V-notch adopted in this test is a 90° V notch.

Simplified equation $Q = 0.0146 \; H^{5/2}$ litres/sec.

where H is in cms.

The coefficient of discharge Cd adopted in the above equation is 0.593 for the material used for V-notch.

LINING TECHNIQUE

Preparation of channel for lining

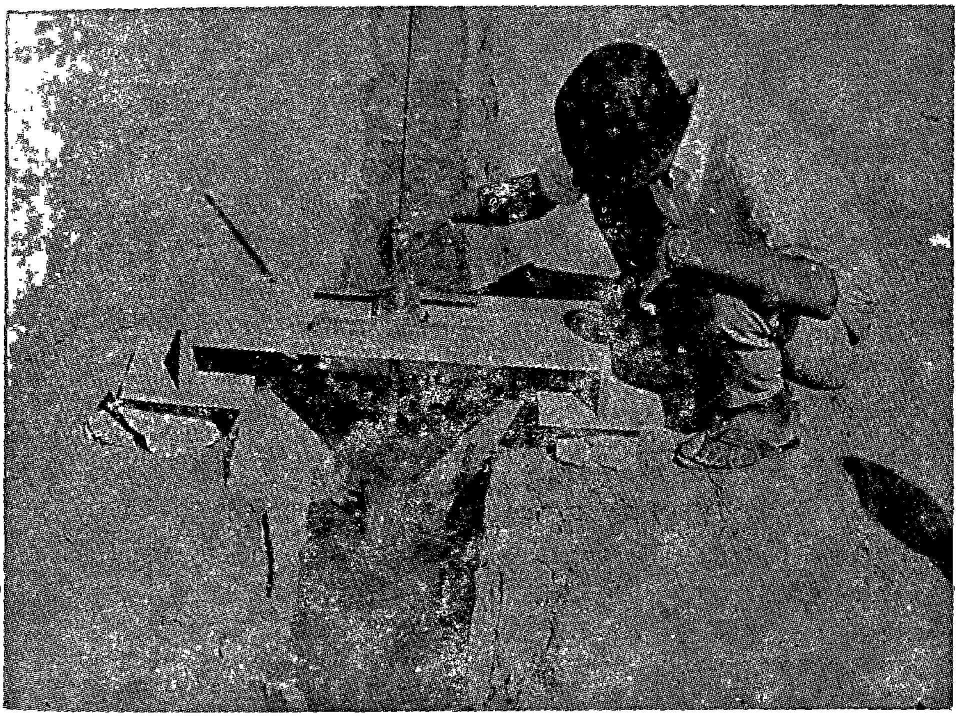
In sandy soils it is sometimes difficult to carry the water even through a short distance. It is seen that permeability of soil can be considerably reduced where soil is mixed with a small percentage of a particular type of bituminous material. This technique suggested by Road Research Laboratory was put to test in small channels constructed at the Institute farm and found to be satisfactory. Janta emulsion, an Asphalt product was used as a bitumen in the test carried out at this Institute.

The technique consists in applying over the sides and bottom of the channels intimate mixture of mud plaster containing a small percentage of Janta emulsion to a thickness of about 1.25 cm and allowing the plaster to dry. Sufficient test trials were conducted to test the efficiency of the method. Such treatment last for six to eight years.

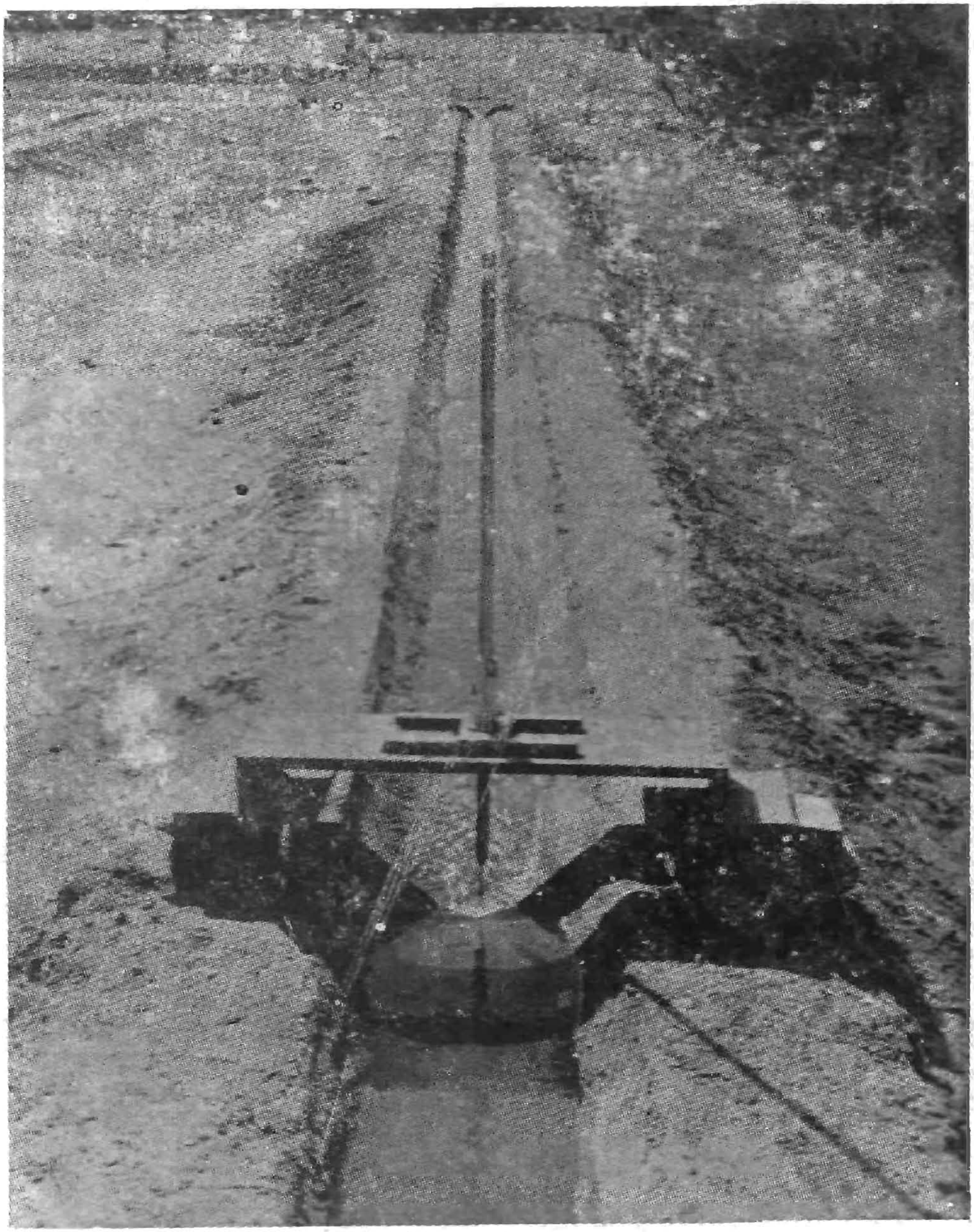
Preliminary operation

Removal of existing vegetation

The irrigation channels already in use have generally a lot of vegetative growth which permits percolation of water



Measurement of flow in the unlined experimental channel.



Measurement of flow in the lined experimental channel.

(Fig. 2a). As a first step, the vegetation should be rooted out and removed. This can be conveniently done by ploughing the surface or loosening it by spade to a depth of about 30 cm and then manually picking the weeds. On loosing 30 cm of embankment generally occupies a height of 45 cm (Fig. 2b).

Preparation of bund

For satisfactory functioning of the channels particularly during monsoon, it is necessary that the embankment should be made fairly strong. The resistance of soil to settlement in wet condition can be considerably increased by compaction. This can be achieved by removing the upper 22.5 cm layer to the sides and compacting the lower 22.5 cm layer at optimum moisture to a thickness of about 15 cm (Fig. 2c). Since the middle portion of embankment has to be removed to a certain depth during the process of making the channel, it is economical to keep the central portion depressed by about 7.5 cm (Fig. 2c). The process of compaction is repeated with the remaining soil stocked at sides so as to have a total thickness of about 30 cm sides and about 20 cm in the centre (Fig. 2d).

The width of the embankment should be such to have about 15 cm flanks on either side of the channel (Fig. 2e).

Channel digging: Depending upon the discharge of water to be passed, a trench of suitable width, generally semi circular is dug in the centre of the embankment. This can be achieved by using a template of correct size. After the trenching has been done, it will be found that about 3 mm of the base and sides is loose. The base is therefore further compacted with a flat iron rammer, but on account of curved surface the sides are passed only with a wooden rammer.

The slope of the drain may be 1 in 200 or any other convenient slope, depending upon the level of the source of water supply and the fields at the tail end. The adopted slope was about 0.5%.

Prevention of weed growth

To avoid the growth of weeds on the bed and sides of the channel, weedicide 2-4D was applied at 1 kg/ha before giving lining treatment.

Application of treatment

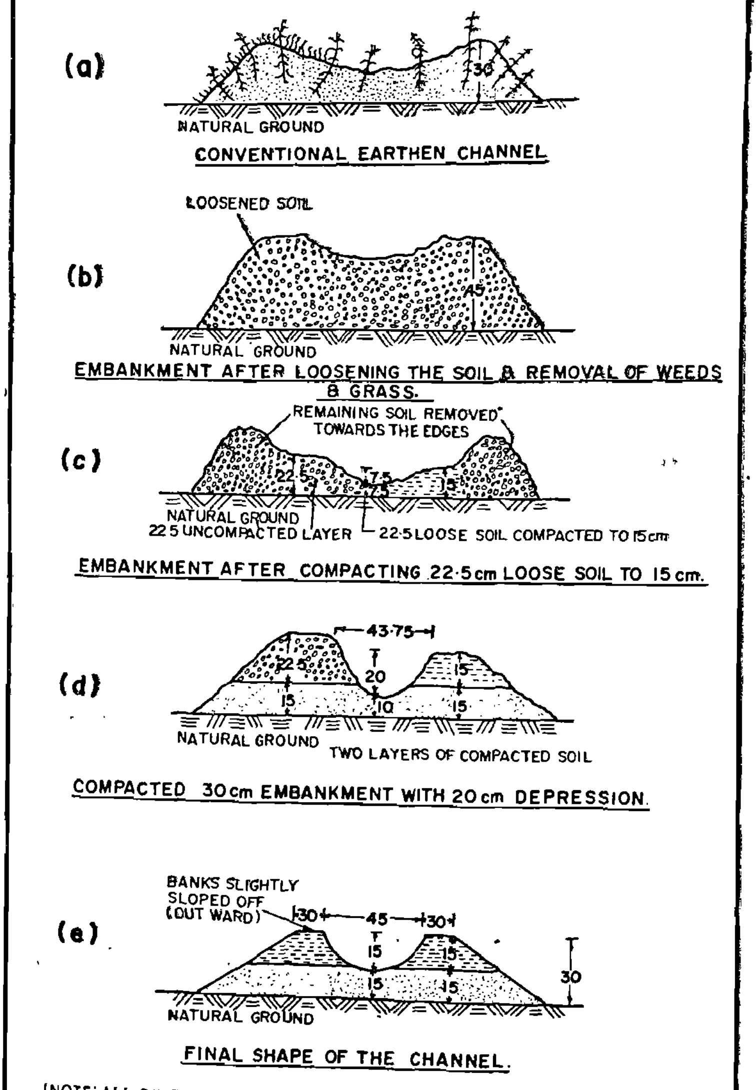
The materials tested were: 1. Mud plaster (Road Research Laboratory specification), 2. Mud plaster (local), 3. Polythene sheeting, 4. Janta emulsion, 5. Soil cement, 6. Bentonite dusting, 7. Fullers earth over compacted soil, 8. *Murrum* with *bhusa,* 9. Tank silt or clay soil with wheat straw, and 10. Control.

1.*Mud plaster* (Road Research Laboratory)

Preparation of plaster: The soil selected for the preparation of puddle should possess enough cohesion. For this purpose, the soil from local village pond around Jodhpur was selected. Every care is taken to prevent cracking of soil on drying.

To further avoid cracking of plaster on drying, the soil is thoroughly mixed

PREPARATION OF FIELD CHANNELS FOR LINING



(NOTE:-ALL DIMENTION IN Cm) FIG-2

with wheat *bhusa* (33.3 kg/cum of soil) and then allowed to set for 7-10 days in the presence of excess water. The puddle is frequently worked up with feet or spade as is normally done in the preparation of ordinary plaster for mud houses in villages. The workability and suitability of the plaster thus prepared was tested by applying it on a small patch of the channel or a mud wall. If cracks still appear on drying, a certain amount of sand or sandy soil is added to the puddle and mixed again.

An hour or two before the application of the mud plaster, Janta emulsion is added to the puddle at the rate of about (0.02 cum) for every cubic metre of dry soil used for making the plaster. The entire mix is then thoroughly worked up with spade.

Plastering: After sprinkling water on the surface of the prepared channel, the plaster is applied with a trowel to a thickness of about 1.25 cm and the surface is then finished smoothly by trowel. Occasional sprinkling of water on the plaster during hot weather will prevent cracks due to rapid evaporation.

Finishing: Hair-cracks may develop after the plaster dries up. These can be closed by the application of a thin slurry, consisting of soil, cow dung and Janta emulsion in the ratio 15:5:1 by weight. After the plaster has dried for about a week, the channel is ready for use.

Repair: Any damage caused by rats or animals can be repaired by plugging the damaged portion wih the plaster originally used.

Precautions

1. Construction should be carried out when there is a minimum slack period of about 3 weeks.
2. Weeds should be removed thoroughly.
4. Repairs should be attended immediately to avoid further damage.
3. Sufficient curing time should be allowed.
5. Passage of cattle over the channel should be prevented.

2. *Mud plaster* (local)

Mud plaster is prepared similar to the method adopted by most of the villagers for their mud houses. The difference between the mud plaster suggested by Road Research Laboratory and the plaster prepared locally is addition of little bituminous substance to keep imperviousness in the soil. If soil contains good percentage of clay, the mud plaster locally prepared by the farmers works well. In order to reduce cracks after drying, little sand and wheat straw is added while preparing the plaster. Rest of the procedure remains same.

Regarding the cost of the lining, it is very cheap since the transportation charges is almost nil as the material required is available in the vicinity of the village. Labour charges also are not much.

3. *Polythene sheeting*

Before the application of the material, the channel is brought to shape and to required size. Any stones, pebbles and weeds if present are to be removed before the polythene sheet is spread. It is useful if any weedicide is sprinkled before the use of polythene. 2-4D in the form of powder is used in this case. However it is suggested that the more effective pre-emergence weedicide Trelfan may be used in order to avoid germination of weed. After the application of the weedicide and removal of weeds and stones, the polythene sheet of the required size is spread carefully without damaging any part of it. Little local soil is spread over the polythene sheet to avoid flying away of the material due to wind.

Any movement of cattle over the channel should be avoided. The polythene used in this case was 150 gauge, transparent 30 metres length and one metre wide approximately. The performance of this material seemed to be quite promising, provided precautions are taken to see that the lining is not damaged by white ants and rodents.

4. *Janta emulsion*

This is one of the best material for checking the percolation loss in channel. The application of this material is made in two ways (1) Premix and (2) Spraying.

Premix: In this method 4 litres of Janta emulsion with 4 lit. of kerosene is thoroughly mixed well under the heat. The required amount was worked out on the basis of desired thickness of lining and type of soil. The mixture is prepared and mixed well and applied to a thickness of 13.0 mm along the bed and sides of the channel. The lining is properly compacted with a trowel to a thickness of about 12.5 mm. For better water proofing, a thin coat with one liter of Janta emulsion may be given over the compacted layer. With this additional coating better imperviousness is assured.

Spraying: This method is very simple. Required quantity of Janta emulsion mixed with kerosene oil to required viscosity to facilitate easy spraying is sprayed to the sides and bed of the channel. More than 70% of the pores are covered. The spraying is continued in several coatings to achieve required thickness.

5. *Soil cement*

This lining is little costlier than other linings. In this type cement 6% by weight is mixed thoroughly with soil and worked with water to desired consistency. The mixed paste is then laid to required thickness on the bed and sides of channel and compacted well to the thickness of about 12.5 cm. This is fairly a durable lining material and its maintenance cost is low. Nowadays soil cement lining has been very popular in all engineering works. Correct proportion of cement depends upon the type of soil, nature of job and the economy.

As the other materials, viz. Bentonite dusting, fuller's earth over compacted soil, murrum with *bhusa* and tank silt or clay soil, were not satisfactory, they were discontinued after one test.

PERFORMANCE OF LINING MATERIAL

(*a*) *Flowing condition*

1. *Control*

The test was discarded due to heavy damage caused due to erosion of soil from the bed and sides as the velocity of water was more than the non scouring velocity. This soil does not stand high velocity, and works under very low velocity condition. The farmers generally adopt tank silt to avoid scouring and to prevent erosion. The loss of water in the control channel was more than 80% under prevailing soil condition in the initial stage of testing. In the subsequent trials, the water loss reduced to minimum.The average loss of water in the unlined channel (control) reduced to about 38% (fig. 5). The test was abandoned after five years.

2. *Mud plaster* (RRL) (Road Research Laboratory)

The seepage loss in this type of lining worked out to be about 25% to 30%. The problem in this lining is damage of lining by white ants. Creation of pockets and pot holes causes heavy loss of water through seepage.

3. *Mud plaster (local)*

Though initially at the start of field trial the seepage loss is less, the loss increases in long run. The average loss of water in this treatment was found to be as high as 38%, which is almost similar to unlined channel. Therefore, due to very poor performance of the lining, high cost of maintenance and high percentage of seepage loss in the subsequent trials, this treatment was abandoned.

Results of field trials conducted on Janta emulsion, polythene sheeting and black clay with *Bhusa* were promising. They are discussed below.

4. *Janta emulsion*

Hourly and daily performance of the lining during 5 days test run has been indicated (Figs. 4 and 3). It is seen from the hourly trials, the initial loss of water at the commencement of the test in all the days were high and ranging from 3.5% to 6% and the loss reduced subsequently from 3.75% on 1st day to 2. 5% on the last day at the end of the day's test. This trend was observed on continuous use of the channel for 5 days. It is difficult to account for this meagre loss of water. This loss may be due to minor holes here and there or due to nonuniformity in thickness of lining. 100% water proofing may be assured if proper workmanship is ascertained. After running the channel continuously for 8 hours every day for 5 days the average daily loss of water in this treatment reduced from 5% to 2.5% (Fig. 3).

Both premix and spray treatments are very effective in controlling loss of water due to seepage. The only difficulty in these treatments is the cumbersome process of mixing and application of hot emulsion. However, considering the overall efficiency and economy, this lining is quite encouraging. This lining may be recommended for adoption by farmers.

5. *Polythene lining*

Number of field trials were conducted with this lining. The results are quite promising. Average daily loss of water ranged from 10% to 14%. Looking to the hourly and daily performance of this lining (figures 4 and 3) the initial loss during 1st to 5th day test trials ranged from 19% to 11% respectively. During the hourly test the loss reduced from 19%, 18%, 14%, 13% and 11% to 12%, 11%, 10.5%, 10% and 9.5% respectively at the end of the test during 5 days run.

The average daily loss reduced from 14.35% on 1st day to 9.65% on the 5th day.

Even with little disturbance the lining gets damaged and causes serious loss of

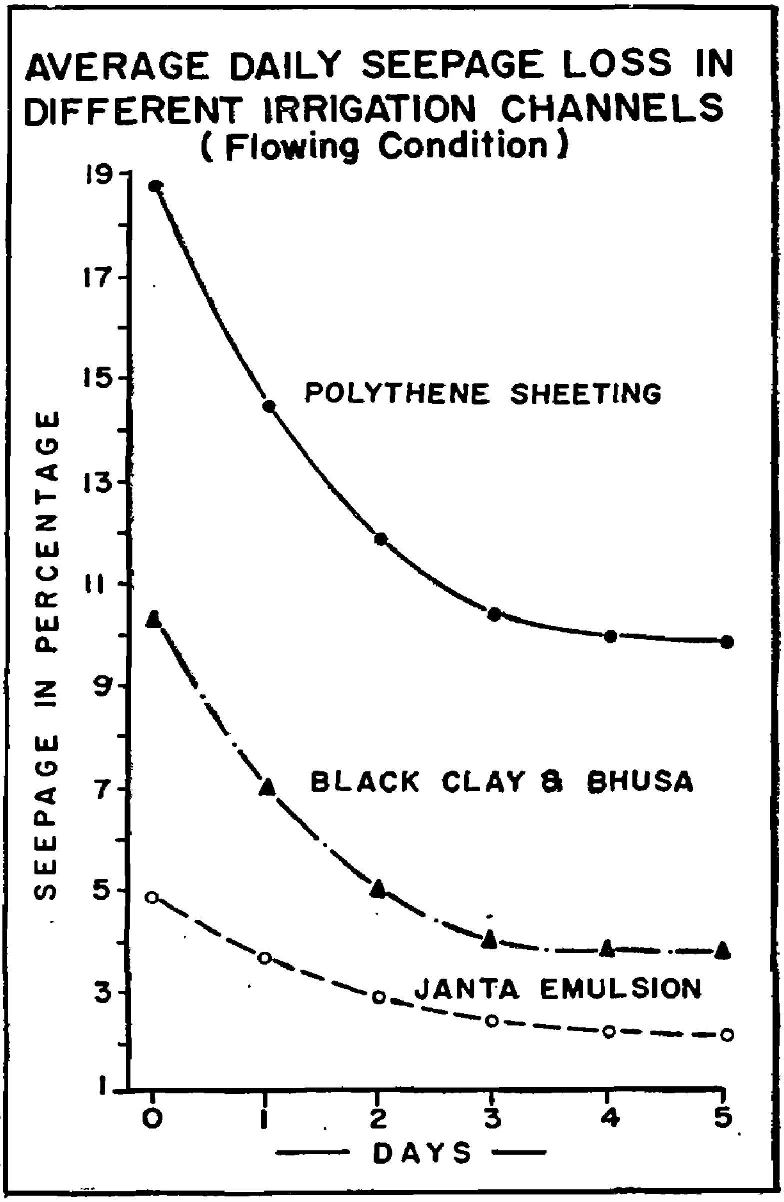

AVERAGE DAILY SEEPAGE LOSS IN DIFFERENT IRRIGATION CHANNELS
(Flowing Condition)
SEEPAGE IN PERCENTAGE
19
17
15
13
11
9
7
5
3
1
POLYTHENE SHEETING
BLACK CLAY & BHUSA
JANTA EMULSION
0
1
2
3
4
5
DAYS

Fig. 3

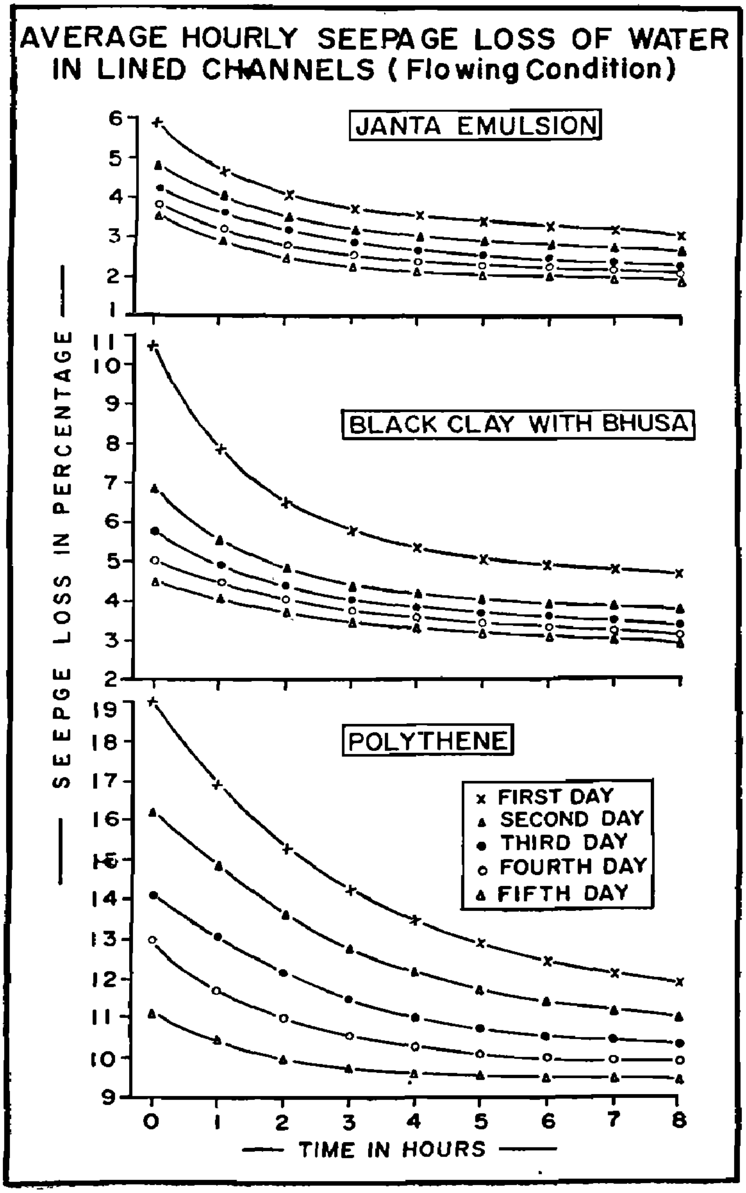

AVERAGE HOURLY SEEPAGE LOSS OF WATER IN LINED CHANNELS (Flowing Condition)
JANTA EMULSION
BLACK CLAY WITH BHUSA
POLYTHENE
x FIRST DAY
SECOND DAY
THIRD DAY
FOURTH DAY
FIFTH DAY
SEEPGE LOSS IN PERCENTAGE
TIME IN HOURS

Fig. 4

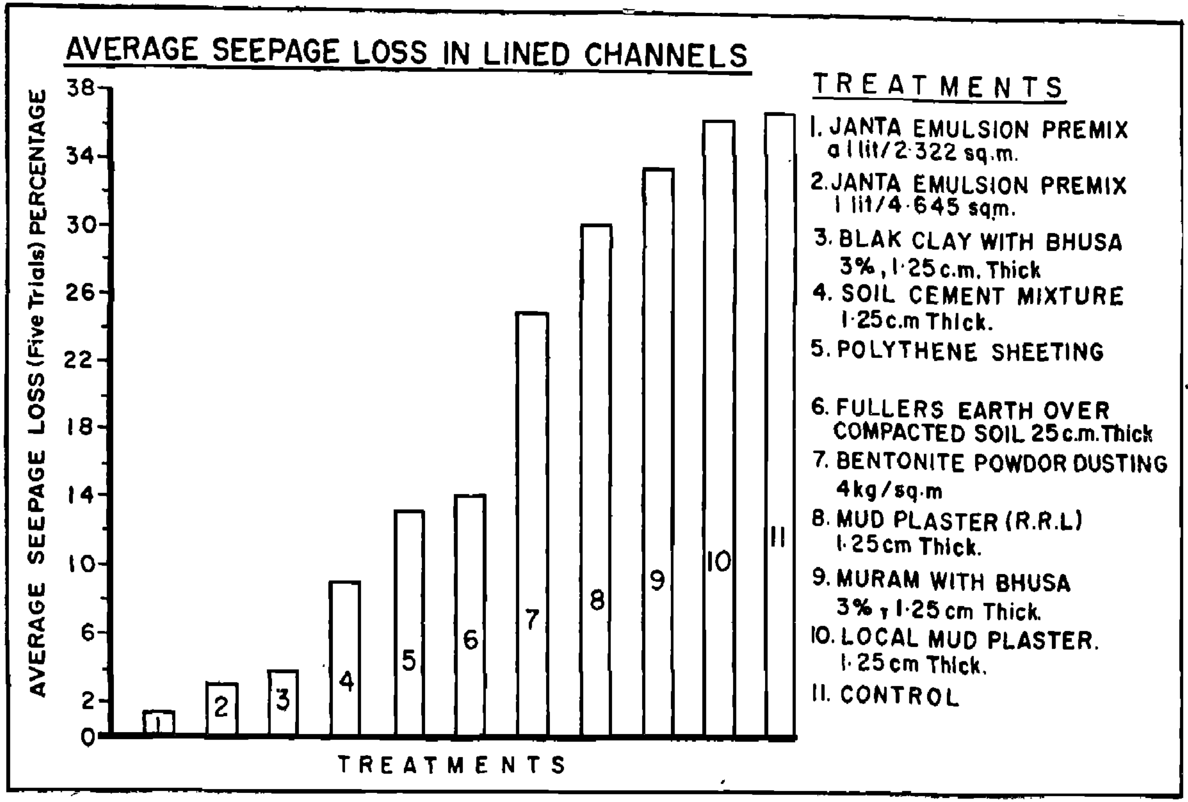

AVERAGE SEEPAGE LOSS IN LINED CHANNELS
AVERAGE SEEPAGE LOSS (Five Trials) PERCENTAGE
38
34
30
26
22
18
14
10
6
2
0
1
2
3
4
5
6
7
8
9
10
11
TREATMENTS
TREATMENTS
1. JANTA EMULSION PREMIX a 1 lit/2·322 sq.m.
2. JANTA EMULSION PREMIX 1 lit/4·645 sqm.
3. BLAK CLAY WITH BHUSA 3%, 1·25 c.m. Thick
4. SOIL CEMENT MIXTURE 1·25 c.m Thick.
5. POLYTHENE SHEETING
6. FULLERS EARTH OVER COMPACTED SOIL 25 c.m. Thick
7. BENTONITE POWDOR DUSTING 4 kg/sq.m
8. MUD PLASTER (R.R.L) 1·25 cm Thick.
9. MURAM WITH BHUSA 3%, 1·25 cm Thick.
10. LOCAL MUD PLASTER. 1·25 cm Thick.
11. CONTROL

Fig.

water. Also the lining will get punctured due to emerging of weeds in the channel causing heavy loss of water. Damage to the lining by livestock movement and emergence of weed if avoided, loss of water due to seepage may be minimised to a greater content.

Sometimes even white ants also may cause serious damage to the lining. Control measures for weeds and white ants are available. This lining, if livestock movement is prevented has great scope for adoption.

6. *Black clay with Bhusa*

From figures 3 and 4 it is seen that this lining also has proved to be efficient in controlling the seepage losses. Table 1 showed that the water loss due to seepage on 1st trial reduced from 7.99% at the 1st hour to 6.91% at the end of the day's test. On 2nd to 5th day of the trial the reduction in water loss was observed to be from 5.57%, 4.32%, 4.16% and 4.08% to 4.00%, 3.30%, 3.15% and 2.92% respectively.

The initial loss at the commencement of the test and loss at the end of the day's trial reduced from 7.99% to 4.08% and from 4.90% to 2.92%.

The average daily loss worked out to be 6.91%, 4.41% 3.90%, 3.85% and 3.67% respectively during 5 days. The average daily water loss reduced drastically from 6.95% on 1st day to 3.67% on 5th day.

However, this lining also is as effective as Janta emulsion in controlling water loss.

If the velocity of water exceeds critical velocity the lining may scour resulting in heavy loss of water. Also cracks in the lining may be developed after drying resulting in heavy seepage loss. This lining needs frequent repairs after every field application. Closure of cracks and pot holes are essential before using the channel for the next irrigation season.

7. *Soil cement*

This is one of the recent materials developed for various use viz., waterproofing roads, water tanks, irrigation canals, etc. This material was tried for small field irrigation channels. This is one of the most durable lining material. The maintenance cost also is low. It hardly required any repair. The seepage loss is considerably higher in this lining. The loss may be minimized to a little extent if the channel is kept in use continuously. If the channel is used intermittently, drying and wetting of the lining may cause cracks and may increase water loss. Also drying may increase the absorption loss. Correct mixture of soil cement may ensure less damage to the lining and less water loss. On use continuously this lining may work out to be efficient.

There is much scope for further study and to develope a correct soil cement mixture for optimum use.

As the other materials namely fuller's earth, Bentonite powder dusting and *Murrum* with *Bhusa* were not effective, the long duration field trials were not conducted and hence were abandoned.

(*b*) *Ponding condition*

Performance of the above materials were also tested under the ponding con-

Table 1. Hourly and daily percolation loss (per cent) in lined field channels (flow condition)

Days	Hours (9 a.m. to 5 p.m.								
	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Daily
					Jantha emulsion				
First	4.68	4.39	3.99	3.60	3.53	3.44	3.28	3 12	3.59
Second	3.75	3.12	3.01	2.92	2.90	2.86	2.85	2.80	2.85
Third	3.27	3.17	2.96	2.84	2.71	2.53	2.30	2.15	2.39
Fourth	3.17	2.97	2.90	2.78	2.74	2.54	2.21	2.00	2.75
Fifth	2.92	2.49	2.32	2.29	2.23	1.69	1.62	1.60	2 10
					Black clay				
First	7.99	7.97	7.11	5.09	5.04	4.93	4.93	4.90	6.91
Second	5.57	4.68	4.52	4.44	4.29	4.12	4.06	4.00	4.41
Third	4.32	4.24	4.05	3.87	3.55	3.52	3.41	3.30	3.90
Fourth	4.16	3.88	3.83	3.81	3.77	3.54	3.28	3.15	3.85
Fifth	4.08	3.87	3.77	3.72	3.70	3.42	3.12	2.92	3.67
					Polythene				
First	16.85	16.08	15.62	14.52	13.82	12.51	12.13	11.85	14.35
Second	15.72	15.10	14.45	13.72	12.93	12 03	11.82	11.12	11.65
Third	14.81	13.51	12.91	11.51	11.90	11.21	10.42	10.02	10.20
Fourth	13.56	12.63	12.41	11.82	10.13	10.63	10.02	9.23	9.85
Fifth	12.06	11.53	11.12	10.63	10.12	9.65	9.06	8.58	9.65

dition. Seepage losses under ponding condition is generally more than in the flow condition due to the standing head of water in the channel. The seepage flow is directly proportional to the head. Therefore, as the head increases seepage losses also increases.

As the study is important under flow condition, further studies under ponding condition have not been carried out. However, seepage losses in various treated channels under ponding condition is given in the Table 2. The loss is depicted through curves shown in figure 6.

Even under the ponding condition, the seepage is minimum in Janta emulsion. The loss decreases from 3.56% to 1.33% on the third day. From the results it is seen that performance of Janta emulsion in any form seems to be best compared to other lining materials. If hourly losses is also considered, the seepage loss in Janta emulsion, is the lowest except in soil, cement and polythene lining. The seepage losses in other tested materials are also low.

MOISTURE STATUS BELOW THE TREATED CHANNEL

Moisture distribution patterns below the lined channels were studied. The distribution patterns below and at the

Table 2. Performance, first to fifth day of trials in channels (Ponding condition)

Type of lining	First	Second	Third	Fourth	Fifth
	Time (days)				
1. Janta emulsion painted @ 1 lit/2.32 sq m	3.56	2.79	1.33	—	—
2. Janta emulsion painted @ 1 lit/4.64 sq m	10.01	4.86	3.28	—	—
3. Black soil and Bhusa 3%, 12.5 mm thick plaster	5.18	3.50	2.97	—	—
4. Polythene sheeting	14.53	8 98	7.92	6.47	6.71
5. Soil cement plaster, 12.5 mm thick	13.17	7.84	6.39	4.66	4.45
6. Control	42.91	37.33	29.73	27.88	25.20
	Time (hours)				
1. Janta emulsion painted @ 1 lit/2.32 sq m	4.53	3.61	3.55	2,92	3.39
2. Janta emulsian painted @ 1 lit/4.64 sq m	18.22	12.34	6.08	6.75	6.65
3. Black soil and Bhusa 3%, 12.5 mm thick plaster	6.80	5.14	5.02	5 18	3.78
4. Polythene sheeting	24.57	13.74	12.25	9.74	12.37
5. Soil cement plaster 12.5 mm thick	21.87	12.84	12.45	10.44	8.24
6. Control	51.16	42.13	40.74	32.25	32.77

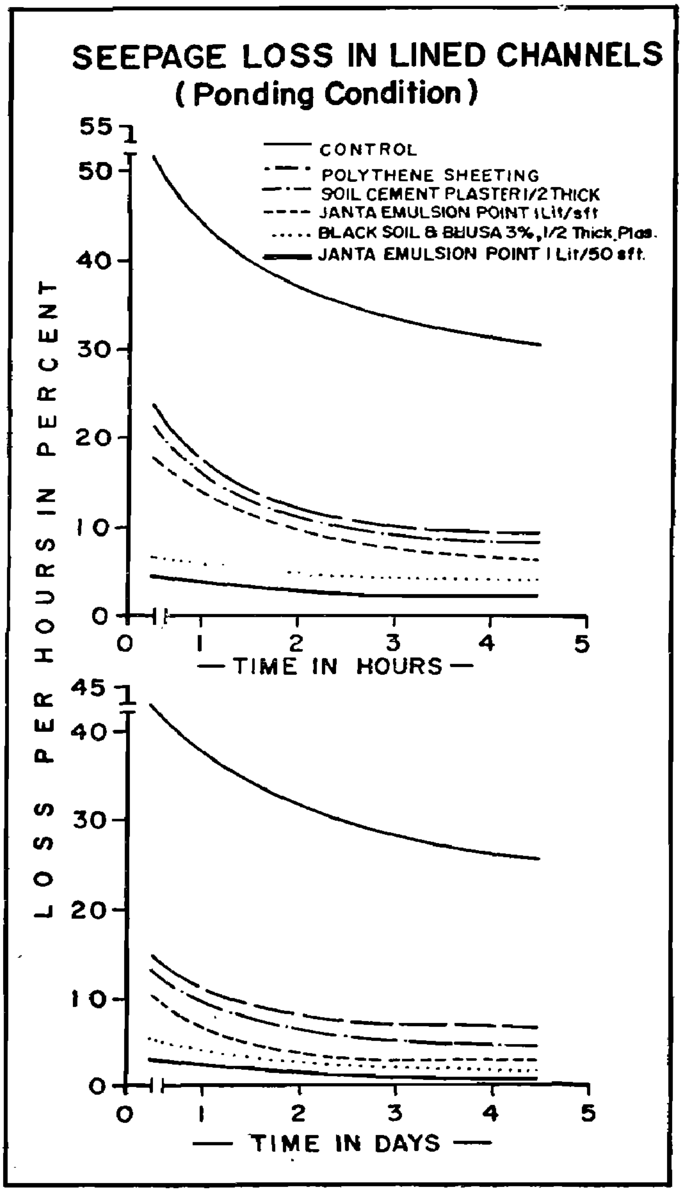

SEEPAGE LOSS IN LINED CHANNELS
(Ponding Condition)
CONTROL
POLYTHENE SHEETING
SOIL CEMENT PLASTER 1/2 THICK
JANTA EMULSION POINT 1 Lit/sft
BLACK SOIL & BHUSA 3%, 1/2 Thick Plas.
JANTA EMULSION POINT 1 Lit/50 sft.
LOSS PER HOURS IN PERCENT
55
50
40
30
20
10
0
0
1
2
3
4
5
— TIME IN HOURS —
45
40
30
20
10
0
0
1
2
3
4
5
— TIME IN DAYS —

Fig. 6

sides of black clay with *Bhusa,* Janta emulsion and polythene lined channels are shown in figure 7. The soil samples for moisture determination were taken at three spots at various depths along three cross sections.

The moisture gradient curves (Fig. 7) indicate the moisture movement both horizontally and vertically down below. In black clay lining, the percentage of moisture decreases as the distance from the sides of the channel increases. In the vertical direction below the channel there is trend of decrease in moisture with increase in depth.

In the case of Janta emulsion the decreasing trend in soil moisture has been observed both in the horizontal and vertical directions. The moisture decreases with increase in depth.

A reverse trend has been observed in the case of polythene lining. Increase in soil moisture at greater depths below the channel has been observed.

At the sides the moisture decreases as the distance from the channel increases. This indicates that polythene lining is less effective at the base than at the sides of the channel.

As explained earlier 100% water proofing may be assured, if proper care is taken while lining the channel assuring uniformity in thickness and correct proportion of the mixture.

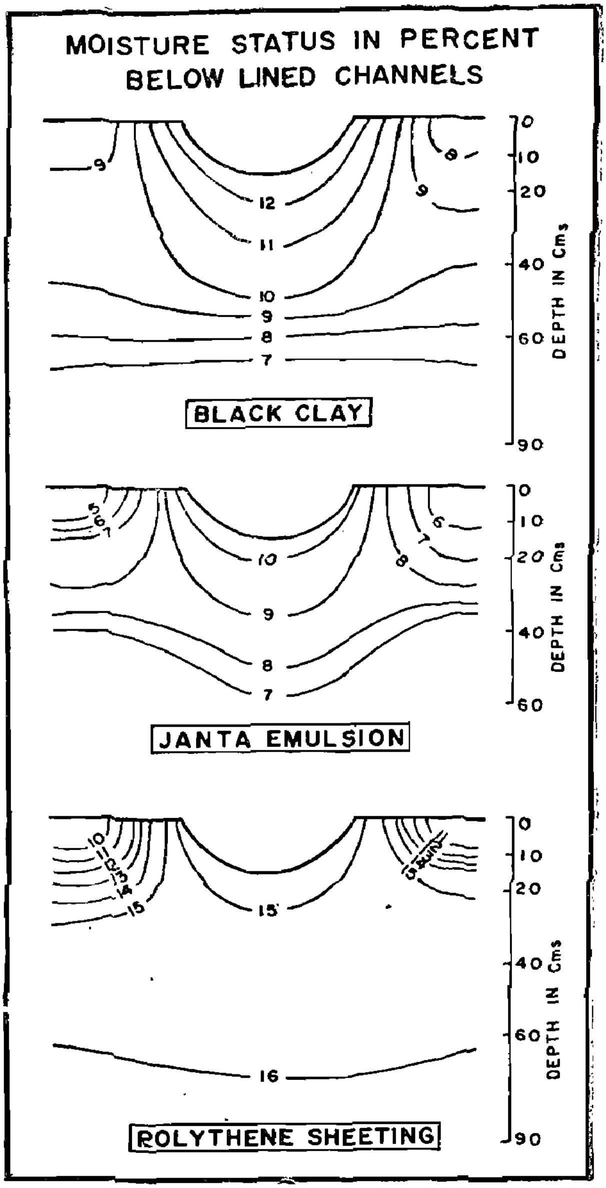
COST OF LINING

The cost of lining in the irrigation channels with different materials were estimated. Cost of lining with Janta emulsion Premix, black clay with *Bhusa* and Polythene sheeting are given in the Appendix, 1. Cost analysis for the other materials have not been included here as they are not economical as against saving water.

Only the lining cost has been worked out for each material on the basis of rates prevailing during 1971. As the construction cost of channel vary from place to place and time to time, only the estimate of cost of lining of channel has been made as given in Table 3.

Table 3. Abstract of cost analysis of lining irrigation channels

Type of lining	Percentage seepage losses over 30 metre length flow channel cross section 45×15 cm depth	Cost of lining per sq metre (Rupees)	Estimated life (years) of lining
1. Janta emulsion premix @ 1 lit/2.322 sq m	1.6	1.50	5
2. Janta emulsion premix @ 1 lit/4.645 sq m	3.4	1.12	3
3. Clay soil with Bhusa 3%, 1.25 cm thick	4.0	0.75	3
4. Soil cement mixture 1.25 cm thick	9.2	0.85	2
5. Polythene sheeting	13.4	1.85	1
6. Fullers earth over compacted soil 1.25 cm thick	14.4	1.12	not durable
7. Bentonite powder dusting 4 kg/ sq m	25.3	0.95	—do—
8. Mud plaster (RRL) 1.25 cm thick	30.4	0.85	2
9. Murum with Bhusa (3%) 1.25 cm	33.4	0.65	not durable
10. Local mud plaster 1.25 cm thick	36.4	0.55	1
11. Control	37.1	—	—



MOISTURE STATUS IN PERCENT
BELOW LINED CHANNELS
BLACK CLAY
JANTA EMULSION
POLYTHENE SHEETING
DEPTH IN Cms

Fig. 7

It is seen from Table 3, cost of lining with polythene sheeting is higher than the costs with Janta emulsion and clay with *Bhusa.*

If the polythene sheeting to the irrigation channel assures 100% reduction in seepage, the lining is worth adopting. But 100% water proofing may not be achieved under the field condition due to various reasons explained earlier. Hence this lining may not be economical for extensive application. The more cheaper lining is clay soil with *Bhusa.* As the life of this lining material is short, this also may not be economical for trying in the farmer's fields in the rural areas. Due to the weed and rodent problem, the life of materials can be 3 to 4 months only. Otherwise the life is 3 to 4 years.

Though the cost of Janta emulsion lining is little higher, considering the life of the lining and amount of water saved, this lining is promising. It is difficult to give the exact cost as the prices of materials and labour charges vary from place to place. The cost also very with the size of the channel. However, an approximate cost has been worked out.

RECOMMENDATIONS

Looking to the merits and demerits of each lining material with regard to the efficiency in performance and cost of lining it is obvious that Janta emulsion seems to be promising one. It has shown good performance in the reduction of seepage loss of water particularly in the desert soils of Rajasthan. The merits and demerits of other materials have already been discussed. Therefore, the major effort to develop a seal has been through with the use of Janta emulsion .This is recommended for extensive application in this region.

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APPENDIX I

APPROXIMATE COST (Rs) OF CONSTRUCTION

BASIS : A parabolic channel to convey discharge of 45780 litre/hour should have 45 cm top width, 15 cm depth and 60 cm wetted perimeter (cost as per the rates of 1971).

A. Janta emulsion (Premix)	Rupees
1. Cost of Janta emulsion 5 litre @ Rs. 1.30/litre	6.50
2. Cost of Kerosene oil 5 litre @ Rs. 0.65/litre	3.25
3. Trenching and ramming of channel for a length of 30 running metre, 2 man days @ Rs. 3.50/day	7.00
4. Cost of mixing and lining including finishing 4 man days @ Rs. 3.50/day	14.00
Total	30.75

If a new embankment is to be made, the cost of 30 m running length will be another Rs. 40.00.

B. *Black clay and Bhusa*	
1. Trenching and ramming of channel for a length of 30 running metre, 2 man days @ Rs. 3.50/day	7.00
2. Puddling of soil and *Bhusa* for a week	3.00
3. Cartage for the required quantity of clay from a distance of 3 km	6.00
4. Cost of mixing and plastering including finishing	14.00
Total	30.00

If a new embankment is to be made, the cost of 30 m running length will be another Rs. 40.00.

C. *Polythene sheeting*	Rupees
1. Cost of polythene sheet 35 metres @ Rs. 0.90/metre	31.50
2. Trenching and ramming of channel for a length of 30 running metre, 2 man days @ Rs. 3.50/day	7.00
3. Spreading of sheet and laying of soil layer over it 2 man days @ Rs. 3.40/day	7.00
Total	45.50

If a new embankment is to be made, the cost of 30 m running channel will be another Rs. 40.00.

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