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S.1 - C.2

METHODS OF SEALING IRRIGATION CANALS IN THE UNITED STATES

Paper

by

R. D. Dirmeyer, Jr.
Assistant Geological Engineer, Civil Engineering Department
Colorado A & M College
Fort Collins, Colorado (U.S.A)

S. I - C. 2

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R. D. DIRMEYER, Jr.,
Assistant Geological Engineer, Civil Engineering Department,
Colorado A and M College, Port Collins, Colorado

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EDITORIAL NOTE

The accompanying paper presents, primarily, methods developed and applied to the sealing of irrigation canals in the United States of America. It is offered in response to Communication 2, Section I, for the XIXth International Navigation Congress in view of the applicability of irrigation canal sealing methods to navigation canals and channels. Experience in the United States on sealing navigation canals and channels is limited. However, much work has been done on irrigation canals. Therefore, the methods and procedures developed in the latter field are offered for cross-application to navigation channels.

G. W. CARLSON,
Colonel, Corps of Engineers, U. S. Army.
Secretary, American Section, PIANC.

INTRODUCTION

Experience on the " means of making watertight the beds and dikes of navigable canals and rivers " is quite limited in the United States. Therefore, the scope of this paper is restricted to a summary of methods used in sealing irrigation canals in the United States — with particular emphasis on those methods that can be used with water in the canal.

It seems likely that conditions in many navigable canals and rivers are somewhat similar to those found in large irrigation canals — especially those that are operated continuously. For example, some of the larger canals in the United States, such as those in the Imperial Valley area of Southern California, are seldom, if ever, dried up. In such instances the uses of conventional canal linings are severely restricted — if not completely eliminated. The commonly used linings, such as those of concrete, asphalt and compacted earth, are normally installed in dry canals. Another restricting factor is the high cost of the conventional linings — especially when combined with the many miles of canal lining needed by most irrigation districts.

Even in areas where the canals are dried up during the winter months, many of the same problems exist. Thus, for many operating irrigation districts, canal linings commonly have been restricted to " trouble spot " applications. This " piecemeal " approach seldom saves much water when it is considered that canal delivery losses commonly range from one-third to one-half of the water diverted, and that most irrigation canals are unlined.

A truly low-cost, mass-production method of canal sealing — that can be used without unwatering the canal — is one of the more important needs of the irrigation industry. Because of this need, considerable research and development work on new canal lining methods and materials is being carried on. Thus, some of the methods that seem to apply most directly to sealing of navigation channels are still very much in the research and development stage. However, available information is included since in any case each canal lining is usually an individual design problem. In many respects a canal lining is like a shoe — for maximum comfort and service the shoe must be carefully fitted to the foot

METHODS FOR USE WITH WATER IN CANAL

Water in the channel being lined is a troublesome obstacle for most canal lining methods, but there are three general types of sealing procedure that can be applied under such conditions :

1. Flowing water used to carry and place sealing materials.
2. Cut-off wall in one or both canal banks.
3. Canal lining layer placed under water.

The above methods are arranged more or less in order of increasing cost.

1. — FLOWING WATER METHODS.

A large part of the costs of commonly accepted canal linings consists of (1) preparing the canal sub-grade, and (2) hauling and placing the canal lining layer. In the silting and the sedimenting methods the sub-grade preparation costs are usually eliminated and the hauling and placing costs are greatly reduced. In both methods flowing canal water is used to carry and place the sealing materials.

SILTING.

Silting with muddy water is as old as irrigation. It has been commonly noticed that muddy water usually will flow farther than clear water in ditches and on irrigated land. In many instances, however, the disadvantages of a very muddy irrigation water, such as the deposition of sand, far overshadow the advantages. Frequently, the advantages go unnoticed until canal cleaning or dredging, or construction of an upstream dam emphazizes that there were, after all, some beneficial aspects to the muddy water.

For example, after Guernsey Dam was completed on the North Platte River near Guernsey, Wyoming, the amount of sediment in the irrigation

Figure I

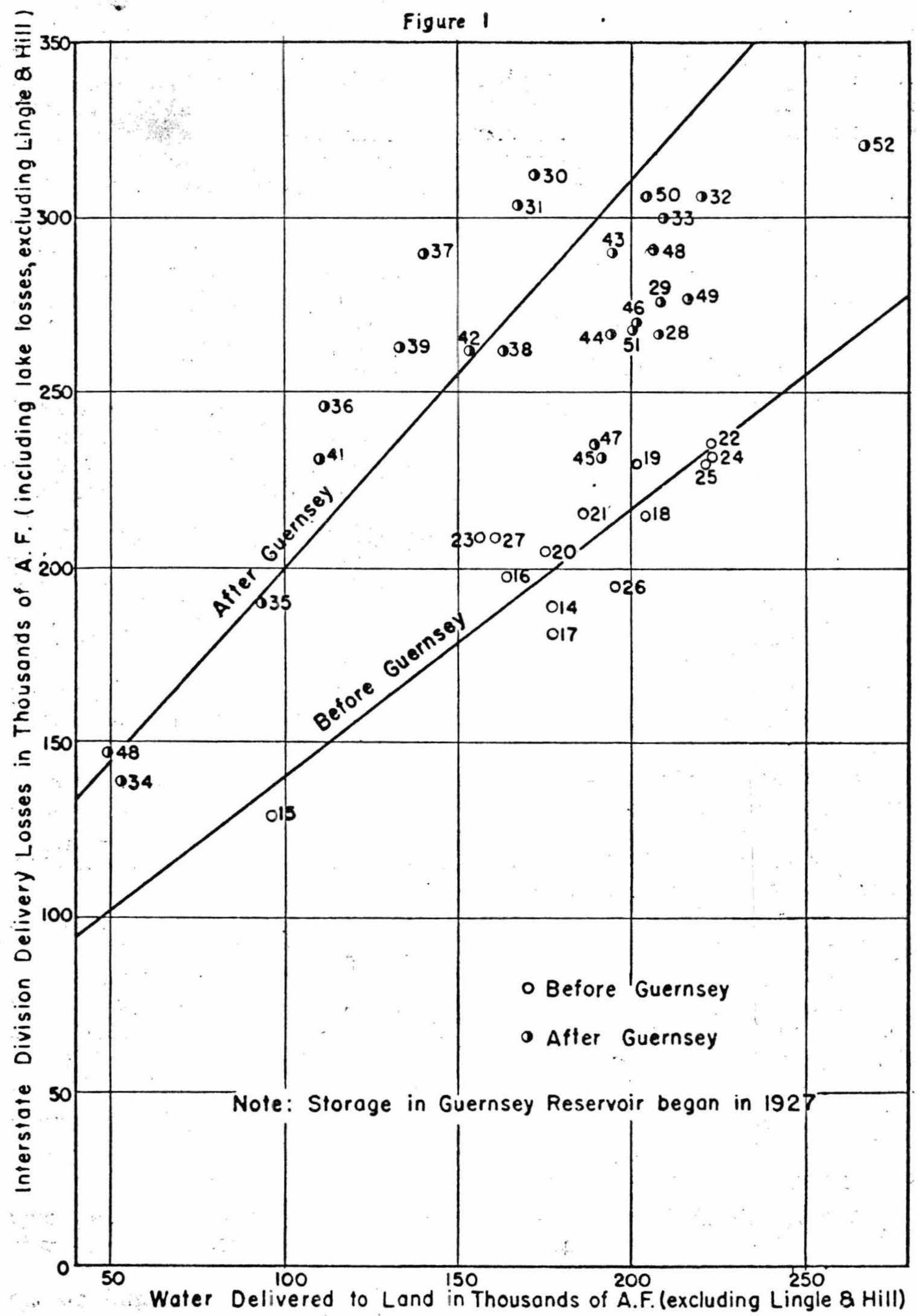

Fig. 1. — Eau distribuée à l'agriculture en milliers de A. F. (pieds par acre).

LEGENDES.

Interstate delivery losses	=	Pertes de distribution entre Etats.
After	=	Après.
Before	=	Avant.
Storage	=	Emmagasinement.

water of the downstream North Platte Project was greatly reduced. The canal cleaning problem was significantly reduced by the clear water, but a serious increase in canal seepage losses (see Fig. 1) and canal bank erosion was experienced. In some reaches of canal a troublesome increase in the growth of submerged water weeds also developed.

In recent years the sealing effect of infrequent muddy water flows in the Interstate Canal has been noted by the operating crew. A slight mud content (max. about 1,000 ppm) in the canal water will almost immediately reduce the over-all losses in the Interstate Canal from about 600 cfs (17 m^3/sec) to 500 cfs (14 m^3/sec) (1). The normal maximum flow is about 2.100 cfs (60 m^3/sec) at the canal headgate. The sealing effect, however, is temporary, lasting about one to two weeks before the silt (2) layer is eroded away.

Silting methods, involving the use of a local silt dumped or sluiced into the flowing canal water, have been tried on many irrigation projects. The best sealing results seem to have been obtained when the silt actually penetrated into the cracks and voids of the leaky canal bed materials.

The most common limitations of silt linings, such as the short life and unpredictable results, seem to relate in many instances to the character of the local material used for silting. The most common limitations of the local " silt " materials are listed below :

1. **Permeability of silt.** — In some extreme cases, local sandy to silty materials of a pervious nature have been used in the silting work. Hovewer, owing to flocculation effects even the most favorable appearing clay materials can produce a relatievely permeable and vulnerable type of silt lining.

2. **Settling tendency.** — When mixed into untreated canal water, most local materials tend to settle to the canal bottom. Thus, the silting action is usually concentrated where the canal water conditions are most favorable for sediment settling and deposition, and not necessarily where the sealing is needed.

3. **Lack of penetration.** — All natural clay deposits contain some sand and silt-size particles. This is unfortunate since just a small percentage of over-size particles can often produce a bridging action over the void openings in the pervious canal bed materials, thus preventing penetration of the smaller, slower settling clay particles. Therefore, the clay fraction of the " silt " is commonly concentrated at the canal bed surface, where it is susceptible to erosion by water, puncturing by animals, deterioration by drying and cracking, or destruction by canal cleaning.

SEDIMENTING.

A research and development project on the use of colloidal clay sediments in sealing irrigation canals has been carried on at Colorado A and M College for the past three years. A coordinated program of field and laboratory research is being used — with almost all of the field installations being done by the cooperators, such as the Bureau of Reclamation and The Central Nebraska Public Power and Irrigation District.

(1) Personal communication from Mr. G. H. Storm, formerly Superintendent, Pathfinder Irrigation District, Mitchell, Nebraska.

(2) Catch-all term — for the purposes of the discussion on silting, it means any sediment ranging in size from sand to silt to clay.

A major objective of the development work is to reproduce and improve on the canal sealing effects of silting procedures while excluding the harmful effects that an uncontrolled silty water can produce in canals and on irrigated soils. (See Photographs 1 and 2).

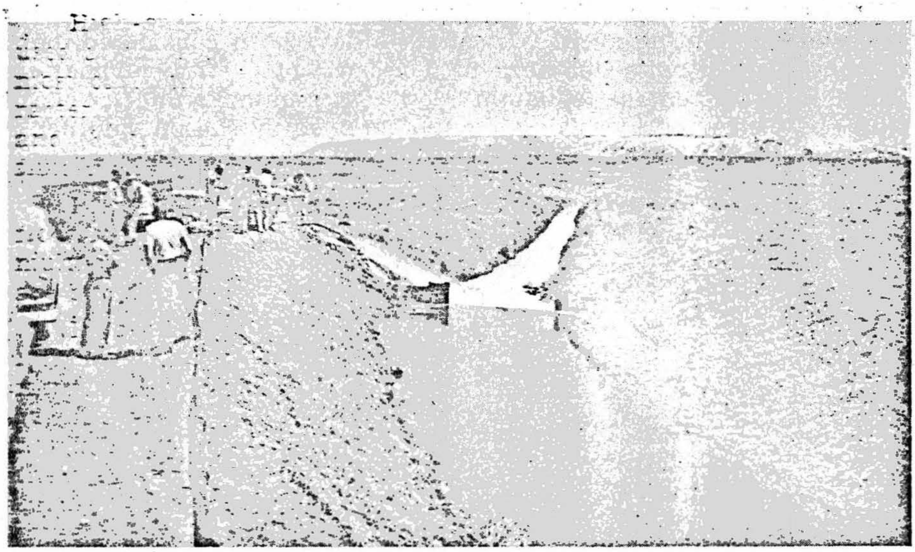

Photo 1.

Bentonite sedimenting operation. Note clear water above check and bentonite water below.

Sédimentation à la bentonite. A noter eau claire en amont de l'obstacle et eau bentonitée en dessous.

Photo 2.

Close-up of cracked natural silt deposit and of bentonite water. Natural cracking utilized to obtain penetration of bentonite water.

Vue en gros plan du dépôt de limon naturel craqueté et eau à la bentonite. - Le craquetage naturel est utilisé pour obtenir la pénétration de l'eau bentonitée.

Experimental installations have been made at field sites on operating canals in (1) loess (wind-deposited silt or dust), (2) river sands and gravels, (3) dune sands, (4) fractured rock (sandstones, siltstones and shales), and (5) silty to clayey alluvial materials.

High-swell bentonite (Wyoming type — drilling fluid grade) has been used as the sedimenting agent. Local clays have been considered, but in most cases the bentonite has been used because of (1) its colloidal characteristics, (2) its general availability, low-cost, and uniformity of quality, and (3) the dispersing methods already developed by the oil well drilling fluid industry.

Polysphosphate dispersants have been used to control sediment flocculation problems caused by (1) hardness of canal water, and (2) multi-valent cation content of bentonite. Other chemical additives also are being evaluated.

In general, good sealing results have been obtained in sand and loessial soils. Less favorable experimental results were produced at the initial site in fractured rock but special sedimenting procedures are being developed for these more openly voided materials. Significantly, however, the experimental costs have usually been less than the value of the water saved in the first season or, stated another way, the cost has usually been less than \$ 1.50/acre foot (\$ 12.16/hectare-meter) of water saved in the first season. Actually, some of the linings are still holding up satisfactorily after three years. The cost of the experimental linings has ranged from ½ to over 20 cents per square yard (.836 m^2) of wetted area in the canal reach being treated.

Based on the results of three years of experimental work, several important characteristics of the bentonite sedimenting method are indicated :

1. In conventional lining methods, accurate location of the leaky zones in the canal bed is desirable since these are the ones to be lined. In the sedimenting method, the sealing action is automatically concentrated in the leaky zones.

2. The normal equipment costs — for sub-grade preparation and placement of canal lining layer — are almost entirely eliminated in the sedimenting method. The only equipment required is for (1) canal cleaning, if needed, prior to sedimenting, and (2) mixing or dispersing the sediment into the flowing canal water at the head end of the section being sealed. Flowing water does most of the work.

3. The method is fast. An entire canal system can be treated in the time it takes for checked-up water to flow through the system. The actual sealing procedure is a water-running operation accomplished by the regular irrigation organization crews.

4. The sedimenting method is a mass-production procedure that offers a truly low-cost type of canal sealing to many irrigation groups that cannot afford the more expensive conventional canal linings.

As previously mentioned, except for a few special cases, colloidal bentonitic clays have been used in the initial experimental work; mainly because they were the most economical and available. However, in areas far from colloidal clay deposits or in some types of pervious materials, other sedimenting agents, such as colloidal asphalt emulsions, might produce the most economical and satisfactory sealing results. Surprisingly, the polyphosphate dispersant alone seems to produce a good sealing effect in certain types of pervious solis. In any case, the same general principles of sedimenting seem to apply.

2. — CUT-OFF WALL METHODS.

From the standpoint of irrigation canals, the flowing water methods of canal sealing are in most instances more economical than the cut-off wall methods, especially when cut-off walls are needed in both canal banks. However, as the size of the channel increases, it seems likely that the areas involved in cut-off walls could become less than those of the pervious zones of the wetted perimeter area of the channel. Therefore, along the larger navigation channels, such as the lower Mississippi River, cut-off wall sealing methods for the levees may provide the most economical and practical sealing methods.

Since water in the adjacent channel in some instances may present certain hazards, it would seem that with adequate precautions the following cut-off wall methods could be applied in reducing seepage from navigation channels — especially seepage through dikes :

1. Trenching methods. — Trench excavated in canal bank and back filled with impermeable materials.

2. Injection methods. — Cut-off wall materials injected through drilled holes in canal bank.

Trenching Methods

Various trenching methods have been used to cut off seepage through canal banks. For example, in some instances the permeable materials in the canal banks are excavated and then re-compacted to bring about the desired reduction in permeability. This procedure normally cannot be used with water in the channel and, therefore, is not discussed at this time.

Another trenching method that can be used in some instances with water in the adjacent channel is the Cronese (1) method. It is a construction method of placing an impervious barrier to depths as great as 100 feet, in most kinds of ground, including quicksand or loose gravel.

Briefly, this is accomplished by using a bentonite slurry to keep the sides of the trench from caving and to furnish an impermeable void filler for the back fill materials of the trench. The impervious wall is constructed by following these steps :

1. A vertical trench is excavated to the desired depth; excavation work may be performed with any suitable tool, such as a trenching machine, drag-line, clam-shell or back-hoe.

2. As the excavation proceeds, the excavated-space is kept filled with a colloidal bentonite slurry. It normally weighs about 64 pounds per cubic foot (1.03 gm/c.c.), and has a viscosity of approximately 15 centipoises. Keeping the excavation filled with this slurry almost completely

(1) Information and photographs of this method supplied by Mr. C. H. Toll, Vice President, Cronese Products Inc. of Tarzana, California.

eliminates caving of the sides of the excavation — even in very unstable ground and with vertical sides.

3. Excavation is then followed by back-filling directly into the slurry-filled trench. If adequately stable, the excavated materials are used for back fill. In any case, suitable materials are used so that the resultant cut-off wall consists of a mixture of fairly coarse materials with the voids completely filled with bentonite.

If properly installed, this type of back fill, even in a relatively narrow trench, is essentially impervious to water. If the cut-off wall intersects or rests upon an impervious layer or bedrock, a satisfactory cut-off of seepage water normally can be accomplished. Even in deep alluvial soils, it is usually possible to extend the cut-off wall deep enough to produce the desired reduction in seepage losses. The layering of the soils usually helps to make this possible.

This method was conceived in 1950 by H. T. Wyatt, and patent rights have been assigned to Cronese Products, Inc. of Tarzana, California.

The first application of this method was in the construction of over 20,000 lineal feet (6 km) of impervious cut-off wall in the levee system of the Union Pacific Railroad Company in the subsidence area of the Long Beach-Los Angeles Harbor. These walls extended underground to a maximum depth of 45 feet (13.7 m). Subsequently, similar walls were constructed in the same vicinity on the property of the General Petroleum Corporation and the Southern California Edison Company. (See Photograph 3).

In 1952-1953 this method was used for the construction of impervious cut-off wall underneath the Kennewick levees, which was a part of the McNary Dam project on the Columbia River in the State of Washington. Here approximately 13,000 lineal feet (4 km) of cut-off wall constructed in the gravel beds along the river bed, before the levees were built. This wall extended in places to a maximum depth of 60 feet (18.3 m) from the ground surface and was built in uncemented gravel. This method was successfully used after all other methods had failed.

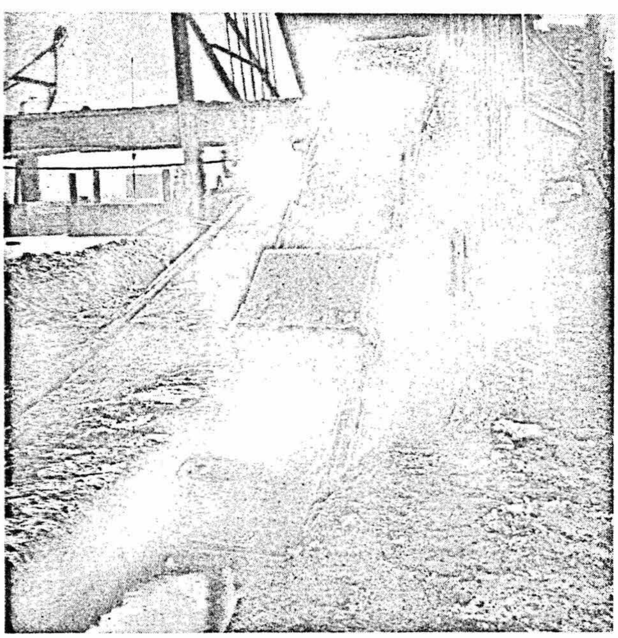

Photo 3.

Trenching operation with bentonite slurry in levee at Terminal Island, California. Trench is 32 inches wide and 45 feet deep.

Construction de tranchée avec distribution de boue de bentonite à l'ile Terminal (Californie). - La tranchée a 32 pouces de largeur et 45 pieds de profondeur.

Within the last year Cronese Products, Inc. has devised much more efficient equipment for the production of the bentonite slurry. This has consequently greatly decreased the cost of construction by this method. The new machinery is much less cumbersome, and therefore, more easily portable than the equipment used on past jobs.

Injection Methods

Several different methods and materials have been used to place cut-off walls by injection methods — especially beneath dams. Materials, such as Portland cement, asphalt and local silts, have been used. (See Photograph 4). While the silt injection work by The Central Nebraska

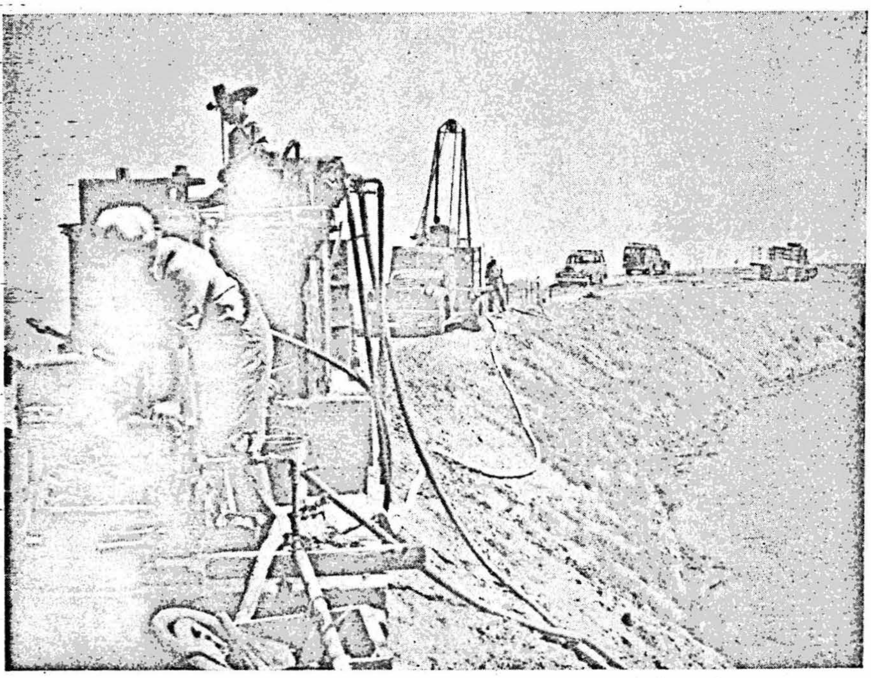

Photo 4.

General view of asphalt grouting using cut-back asphalt. Mixing equipment actually designed for cement grouting, primarily on dam foundations.

Vue générale d'un coulis utilisant du cut-back d'asphalte. L'équipement du mélangeur était construit initialement pour le coulis de ciment dans les fondations de barrages.

Public Power and Irrigation District is a rather specialized example, it is an outstanding example of procedures successfully developed by project engineers to solve a particularly troublesome and dangerous settlement and seepage problem. Therefore, the work has been selected as the case in point for this discussion (1).

The silt injection method was developed as a practical means of

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(1) Information furnished by Mr. George E. Johnson, Chief Engineer, The Central Nebraska Public Power and Irrigation District, Hastings, Nebraska.

consolidating loessial soils by pumping a silt slurry into the moist soil. The success of this method depends on the escape of slurry water and soil moisture out through the soil surrounding the area being consolidated. If the excess moisture stays in the injected area, then the soil will remain liquid. If the injection work is continued under these conditions, failure is almost certain. For this reason, before starting extensive silt injection work, comprehensive feasibility tests should be made in the field to be certain that the soil will consolidate when injected with slurries of local materials.

The irrigated area of The Central Nebraska Public Power and Irrigation District is underlain by wind-deposited loessial soils ranging in thickness to over 100 feet (30.5 m). The loess is underlain by an extensive gravel layer. Because of its settlement characteristics when saturated, loessial soils have long been considered as an inadequate foundation for hydraulic structures, but extensive field and laboratory tests prior to construction revealed :

1. The undisturbed loessial soil had considerably more permeability in a vertical direction than in the horizontal.

2. The soil, when saturated, would consolidate and settle several feet under the weight of structures or overlying soil.

3. The soil, when consolidated, had adequate bearing capacity.

4. The adjustment of soil grains during consolidation would close the pores sufficiently to prevent excessive leakage.

After investigating several other consolidation methods, the silt injection method was selected as the most feasible. Using his method, the foundations under most of the major concrete structures were consolidated, as soon as the moisture penetrated into the soil and before the water table had risen appreciably. By timing the operations in this manner major foundation settlement problems were averted. The structure foundation work was followed by silt injection work in the banks of the main Supply Canal. (See Figure 2). The latter work has reduced the seepage losses on the Supply Canal by about 150,000 acre feet (18,500 hectare-meters) per year.

3. — UNDER WATER PLACEMENT METHODS.

Various methods have been used to place a canal lining layer under canal water and without interrupting the delivery of irrigation water. Usually the methods consist of a local sealing material adapted for use under local conditions. A few of the methods that seem to have a potential application in navigation channels are outlined below.

Fig. 2. — Equipment setup for silt injection on one side of canal.
Equipement pour injection de limon sur un côté du canal

LEGENDES.

Silt wells	=	Distributeur de limon.	Gravel	=	Gravier.
Pump	=	Pompe.	Silt	=	Limon.
Slurry	=	Boue.	Hose	=	Tuyau.
Pit	=	Puits.	Elbow	=	Coude.
Mixer	=	Mélangeur.	Strainer	=	Filtre.

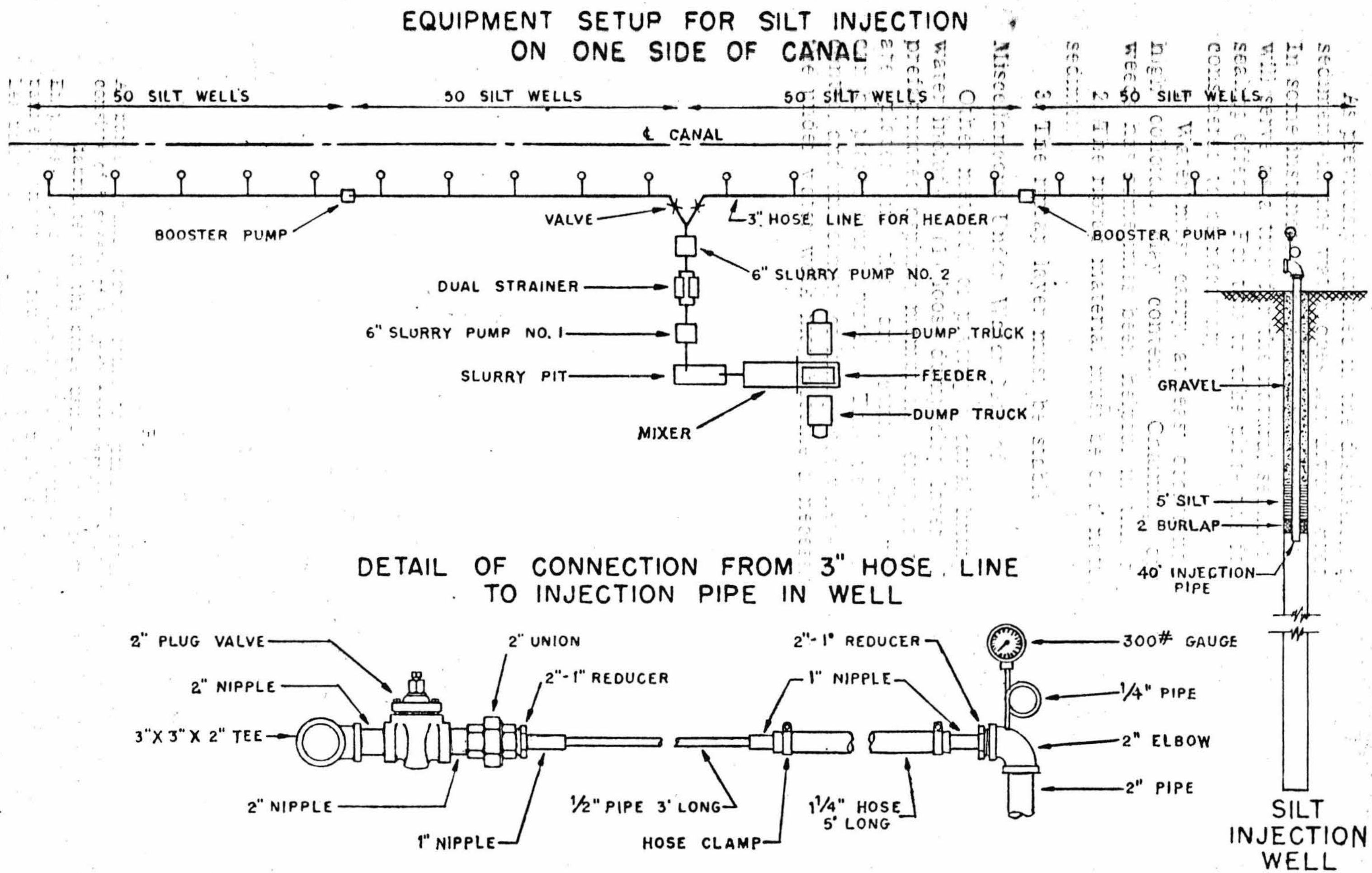
EQUIPMENT SETUP FOR SILT INJECTION
ON ONE SIDE OF CANAL
50 SILT WELLS
50 SILT WELLS
50 SILT WELLS
50 SILT WELLS
℄ CANAL
BOOSTER PUMP
VALVE
3" HOSE LINE FOR HEADER
BOOSTER PUMP
6" SLURRY PUMP NO. 2
DUAL STRAINER
6" SLURRY PUMP NO. 1
DUMP TRUCK
SLURRY PIT
FEEDER
DUMP TRUCK
MIXER
GRAVEL
5' SILT
2 BURLAP
40' INJECTION PIPE
DETAIL OF CONNECTION FROM 3" HOSE LINE
TO INJECTION PIPE IN WELL
2" PLUG VALVE
2" UNION
2"-1" REDUCER
2"-1" REDUCER
300# GAUGE
2" NIPPLE
1" NIPPLE
1/4" PIPE
3"X 3" X 2" TEE
2" ELBOW
2" PIPE
2" NIPPLE
1/2" PIPE 3' LONG
1 1/4" HOSE 5' LONG
1" NIPPLE
HOSE CLAMP
SILT INJECTION WELL

Fig. 2

Gravel Trap for Silt.

As previously outlined in the discussion on silting, a favorable natural sediment in the water does not always produce a lasting sealing effect. In some instances, a gravel or rock riprap layer placed for erosion control will serve as a trap for the natural sediment and produce a more lasting sealing effect. For this to take place the following conditions are usually considered to be necessary :

1. Water must carry, at least occasionally, a natural sediment of a high colloidal clay content. Chaining operations to control aquatic weeds has sometimes been helpful in this regard.

2. The riprap material must be of a nature such that it will trap the sediment.

3. The riprap layer must be stable.

Miscellaneous Under Water Methods.

Other methods of placing a canal lining layer under flowing canal water include : (1) loose dump clay layer, (2) asphalt injection, and (3) prefabricated asphalt membrane (exposed type). Normally these linings are placed in the dry canal, but where necessary the linings can be placed under water. This usually involves extra cost and less control and uniformity of lining, but where the canals cannot be dried up, the under water work may become a necessity.

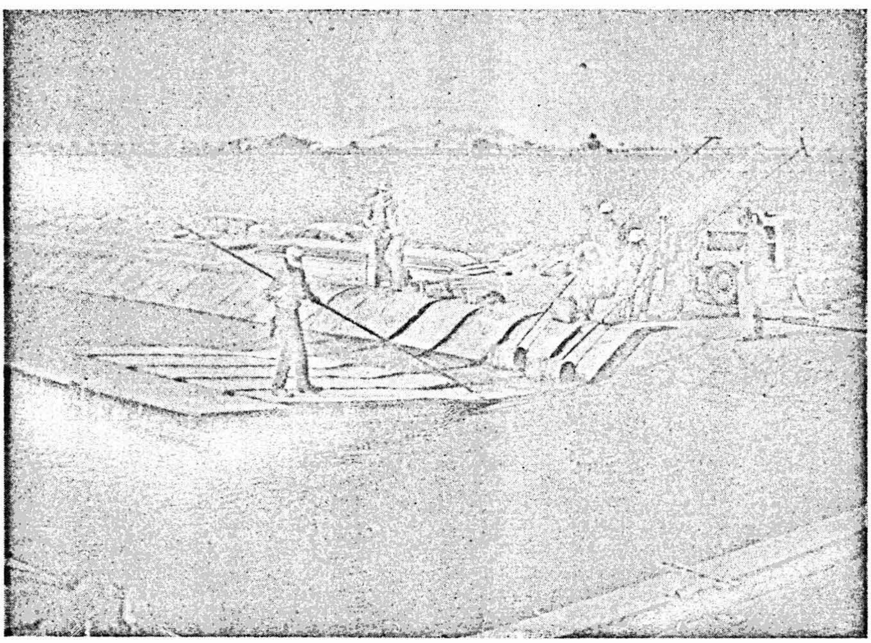

Photo 5.

As barge is pulled across canal, the panel is carefully submerged. Each panel consists of 5 sheets of ½ inch thick asphalt prefab material. The panels were fabricated on the barge using sheets 4 feet wide and 23 feet long.

En poussant le ponton vers le canal, le panneau est submergé avec soin. Chaque panneau comporte 5 feuilles de ½ pouce en matériau asphaltique préfabriqué. Les panneaux sont fabriqués sur le ponton en utilisant des feuilles de 4 pieds de large et 23 pieds de longueur.

Loosely placed clay layers have been used for seepage control in a number of canals. For example, on the All-American Canal such a layer was placed by spilling the clay down the bank, into the flowing water, and over the pervious areas in the canal bank. The clay was then protected from erosion by a riprap cover material. On larger canals this type of blanketing is probably limited to the bank areas and to be successful the clay material must be impermeable when placed loosely. For lasting sealing effects the layer usually must be protected by a riprap layer to prevent removal by water erosion and wave action.

The asphalt injection method has been used experimentally by the U. S. Bureau of Reclamation in a canal near Yuma, Arizona. A special spray bar with nozzles that drag in the sandy canal bottom materials is used to inject the asphalt. Uniform sealing with this method is difficult.

A prefabricated asphalt membrane that is assembled on a barge and then lowered to the canal bottom as a continuous sheet has also been tried by the Bureau of Reclamation in canals near Yuma, Arizona. (See Photograph 5).

DRY CANAL METHODS

Most of the methods commonly used in lining irrigation canals in the United States are applied under dry canal conditions and, quite often, on a relatively small scale. Thus, many of the methods do not seem applicable for use in navigation channels, except perhaps with considerable adaptation and modification. For these reasons and because of the time and scope limitations placed on this paper, the discussion of these lining methods must be brief and many of the common methods are not directly mentioned. For descriptions of procedures and materials used in these commonly used methods, several excellent references are listed in the Bibliography at the end of this paper. Photographs of most of the commonly used methods are included.

In general, the normal canal lining methods can be grouped into three types : (1) treatment of in-place soils with sealing action or additive, (2) buried membranes of impermeable materials, and (3) a surface layer of impermeable materials. The methods are arranged more or less in order of increasing cost.

TREATMENT OF IN-PLACE SOILS.

Usually the most economical linings — from the standpoint of initial construction cost — are those involving the treatment of the in-place canal bed (and bank) materials, either by compaction or by the addition of a sealing agent.

Compaction of in-place soils. — If the canal section is relatively uniform with fairly flat side slopes and if the pervious soils are of a favorable nature and condition, compaction of the in-place canal bed materials with a sheep's-foot roller is sometimes effective. The sealing effect is, however, usually rather temporary owing to drying or freezing effects or the burrowing action of aquatic weeds or animals.

Addition of sealing agent. — Two general methods of adding a sealing agent to the in-place pervious soils have been used : (1) agent sprayed on pervious soil zones, (see Photograph 6) and (2) agent admixed into pervious soil (see Photograph 7). Various sealing agents have been used,

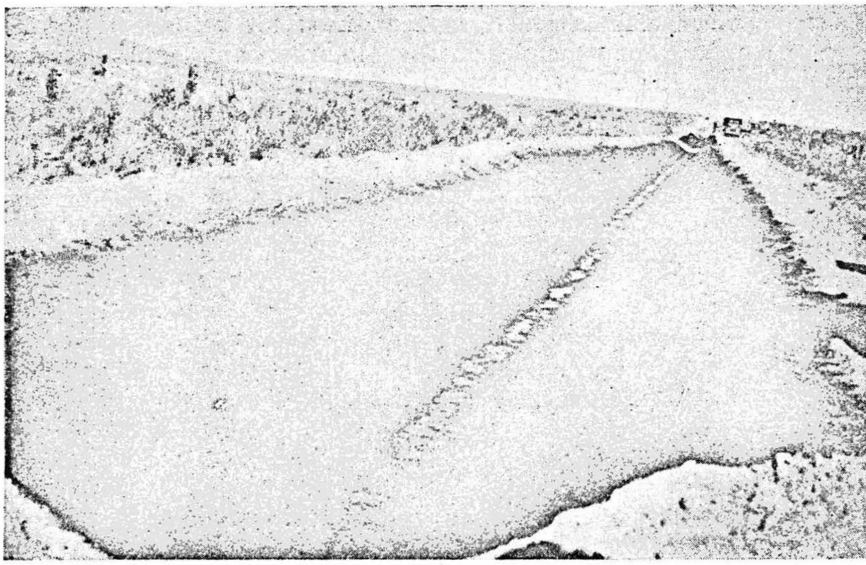

Photo 6.

View of primed earth lining where two to three gallons per square yard of various cut-back asphalts were applied by surface spray in 6 to 10 applications.

Vue d'un revêtement en terre où deux à trois gallons par yard carré de différents cut-baks furent appliqués par aspersion en 6 à 10 applications.

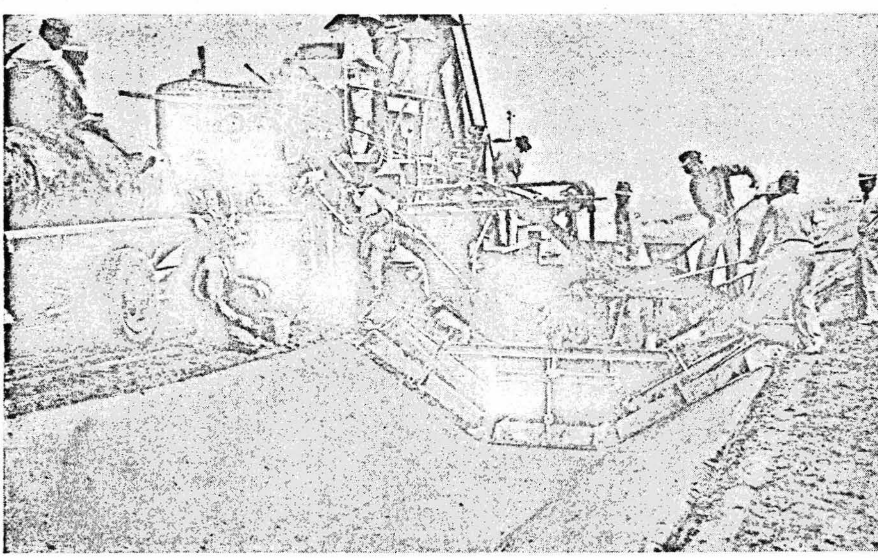

Photo 7.

Travelling plant mixer and subgrade-guided slipform used in placing plastic soil cement lining in West 11.5 lateral of W.C. Austin Project, Oklahoma.

Equipement mobile comportant un mélangeur et un gabarit guidé utilisé pour placer un revêtement en sol-ciment-plastique au 11.5 latéral Ouest du projet W.C. Austin (Oklahoma).

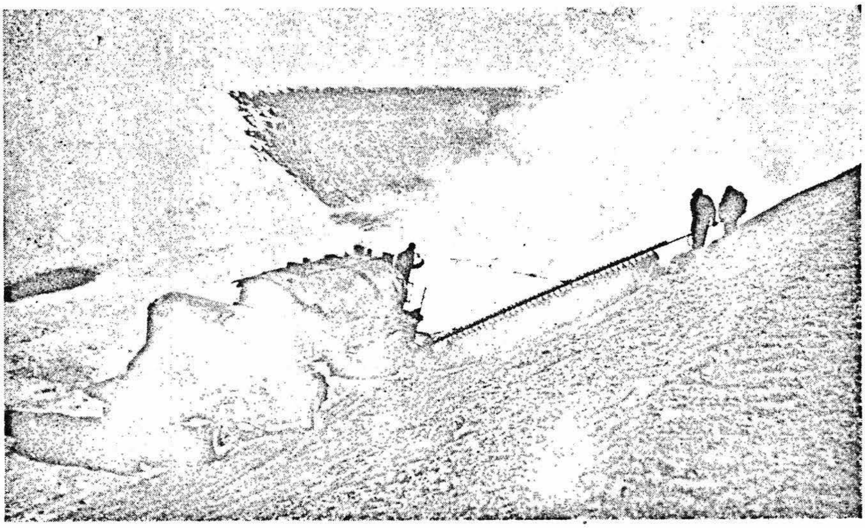

Photo 8.

Using distributor spraybar in the application of catalytically blown asphalt **membrane**. Soil and gravel used for cover on membrane.

Utilisation d'un distributeur à aspersion pour l'application d'une membrane **asphaltique** soufflée catalytiquement. La terre et le gravier sont utilisés pour couvrir la membrane.

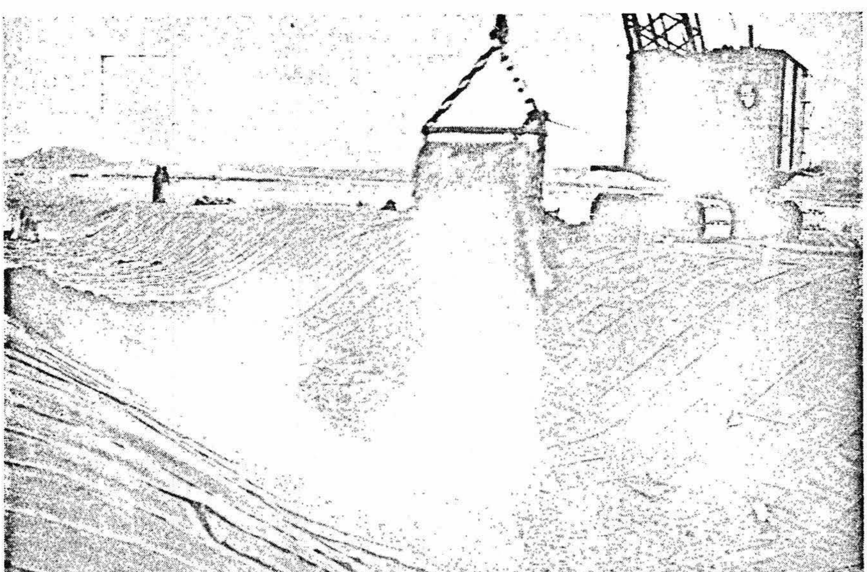

Photo 9.

Placing earth cover over prefabricated lining. Cover is cast in direction of lapped-joint to prevent dirt from entering and fouling joint.

Placement d'une couverture en terre sur le revêtement préfabriqué. La couverture **est** coulée dans la direction du chevauchement des membranes afin de prévenir que les sâletés entrent et souillent le joint.

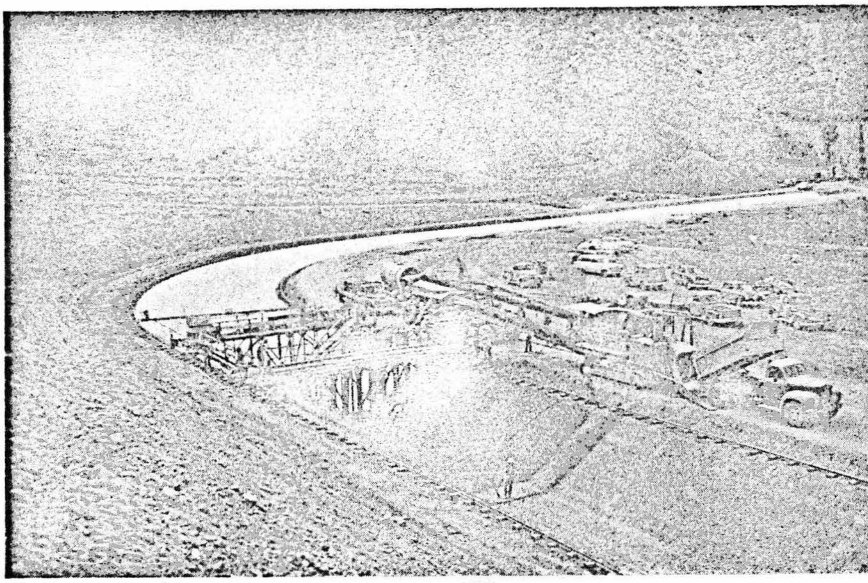

Photo 10.

Placement of concrete lining with slip-form in Weber Basin Project, near Ogden, Utah.

Placement d'un revêtement en béton par gabarit glissant dans le Projet du Bassin Weber, près d'Ogden, Utah.

Photo 11.

Placement of shotcrete canal lining or pneumatically applied Portland cement mortar.

Placement de revêtement en « Shotcrete » ou mortier de ciment Portland appliqué pneumatiquement.

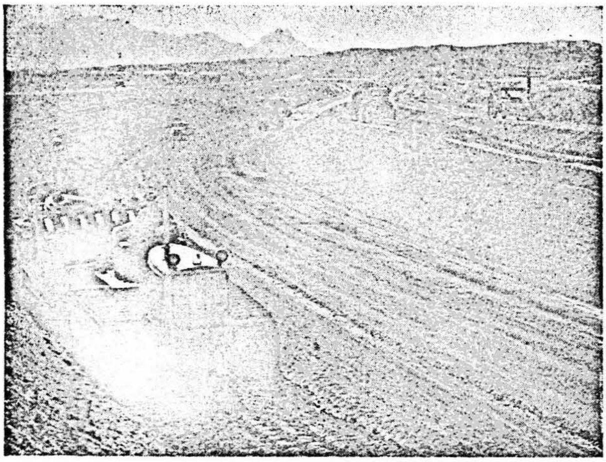

Photo 12.

Placing and compacting operations during construction of heavy compacted-earth lining on Wellton-Mohawk Canal, Gila Project, Arizona.

Placement et compactage pendant la construction d'un revêtement en terre fortement compactée sur le Canal Wellton-Mohawk, Projet Gila, Arizona.

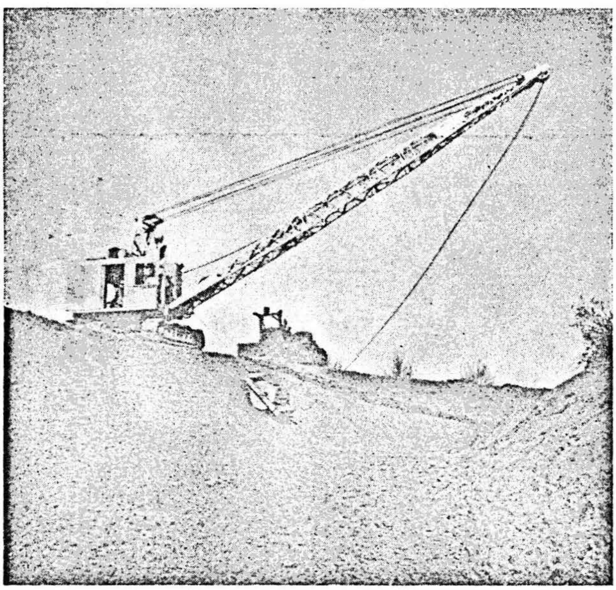

Photo 13.

Transverse compaction of thin earth lining (two 6-inch layers). W. C. Austin Project, Oklahoma.

Compaction transversale d'un mince revêtement de terre (deux couches de 6 pouces). Projet W.C. Austin, Oklahoma

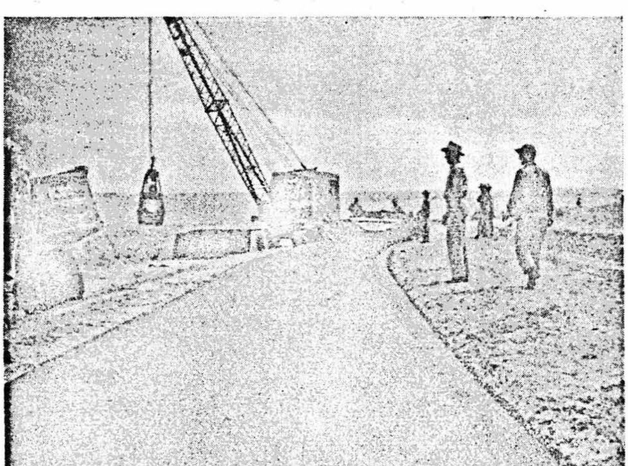

Photo 14.

Placing 2-inch thick hot-mix canal lining with a slip-form.

Placement d'un revêtement de 2 pouces de mélange à chaud au moyen d'un gabarit glissant.

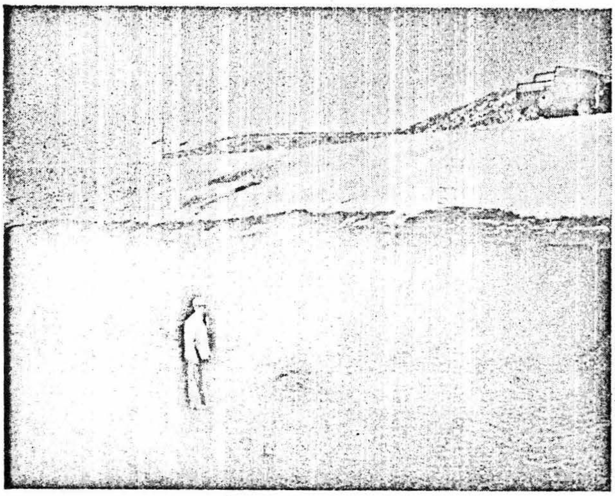

Photo 15.

View of completed installation consisting of asphalt membrane with penetrated macadam cover.

Vue d'un revêtement achevé consistant en une membrane d'asphalte avec couverture en macadam à pénétration de gravillons enrobés.

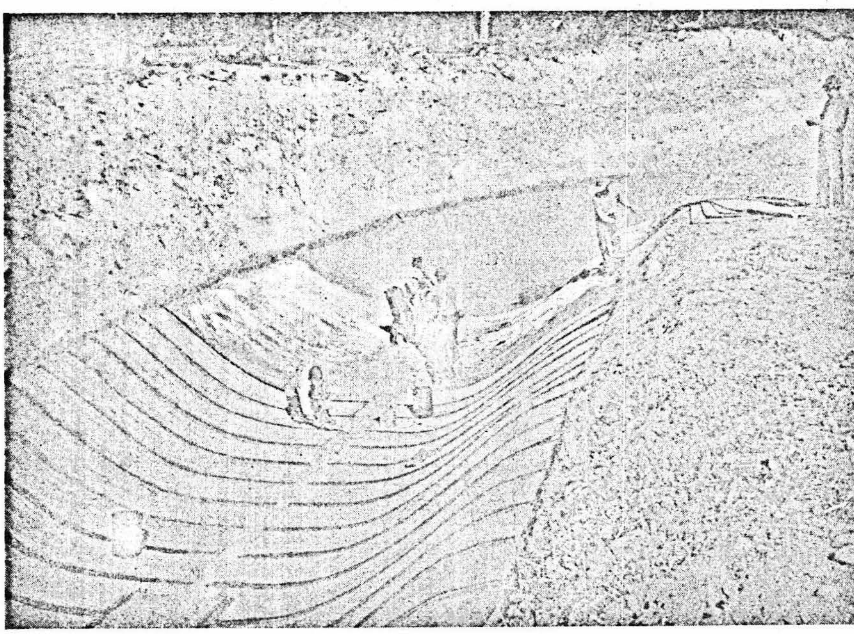

Photo 16.

Installation of prefabricated sheets 3 feet wide, 12 feet long, and ½ inch thick over prepared and sterilized subgrade.

Placement de feuilles préfabriquées de 3 pieds de largeur, 12 pieds de longueur, et ½ pouce d'épaisseur sur fondation préparée et stérilisée.

such as asphalt, local clays, Wyoming bentonite, Portland cement, and chemicals of various kinds and actions. In many cases compaction of the treated soils is also included as part of the procedure. Exellent to poor results have been obtained by these methods; adaptation to site conditions seems to be especially important in these applications.

BURIED MEMBRANES.

To conserve on materials and costs, several types of buried membrane linings have been developed where the excavated sub-grade materials are used as a cover for a relatively thin membrane of impervious material. Local clays, bentonite and asphalt materials have been used for the impervious membrane. The asphalt materials have been applied by two methods: (1) sprayed (hot, usually) (see Photograph 8), and (2) prefabricated strips (shipped in rolls) (see Photograph 9). A protective layer of gravel or rock riprap over the local soil cover material is usually required for protection from erosion. Where properly designed and installed, these linings are giving excellent service.

SURFACE LAYER.

The oldest and most widely accepted linings are the surface layer types of concrete, asphalt and earth linings. On new construction and where the job is large enough to use heavy construction machinery, the costs of these types of linings can be surprisingly low. If the channel can be dried up long enough, one of the surface layer types of linings may prove to be most satisfactory. (See Photographs 10 through 16).

CHOICE OF LINING TYPE

In regard to irrigation canals, no one lining is suitable for all conditions to be encountered and the costs for any one type of lining will vary with each job. Thus, careful analysis of canal conditions and materials are requisites to producing a satisfactory lining. In addition, the cost of maintenance and probable life of lining should also be considered. It seems likely that the same factors need to be considered in the choice of lining or sealing method for a navigation channel.

For example in irrigation, concrete is the most commonly accepted lining material. It is usually highest in first cost, in many instances the lowest in maintenance costs, and perhaps longest in useful life — at least from the standpoint of available service records. It is more resistant to erosion than most other types of linings and because of its beam strength it can bridge short reaches of poor subgrade support; therefore, it is preferable where high water velocities exist or where safety is of primary concern. Concrete linings eliminate break-outs due to burrowing animals and effectively limit most aquatic weed growths. However, adverse subgrade conditions, frost heaving, excessive hydrostatic pressures beneath the linings, poor quality of concrete, faulty design or construction, etc., have caused failures of concrete linings.

It is possible to design concrete linings to fit almost any condition, but in many instances less costly materials and methods may be equally satisfactory. In areas where high ground water or expansive soils are found, some of the more flexible types of lining, such as those of earth and asphalt, may be more desirable than concrete.

Where suitable materials are available within a short haul distance, the compacted earth linings are commonly lower in first cost in large installations than most of the other commonly accepted linings. Of course, if adequately designed and properly installed some of the other newer and less developed methods of seepage control, such as sediment linings or cut-off walls, may be considerably more economical than the conventional layer type of earth linings. This may be especially true of the cut-off wall methods when the wetted area of large channels is considered. The maintenance costs of earth and sediment linings should be about the same as an unlined channel.

Asphalt membrane linings have a distinct advantage over most of the other lining methods when (1) the lining must be installed in freezing weather, (2) boggy soil conditions prevent the use of heavy construction equipment, and (3) the time for construction is limited. Here again, however, the methods that can be used with water in the canal deserve careful consideration. Since it is necessary to keep the membrane covered at all times, the maintenance costs for the membrane linings are somewhat higher than for an unlined canal.

In any case, it seems wise to consider each canal seepage problem as an entirely new and individual problem. Obviously experience from other canal lining work is helpful, but actually each canal lining investigation almost always uncovers several unique and new problems that should be provided for in the designs. Good engineering will always pay for itself.

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RESUME

Les Etats-Unis n'ont qu'une expérience limitée en matière d'imperméabilisation des lits et des berges des voies navigables. En conséquence, le présent rapport se limite à passer en revue les méthodes utilisées pour imperméabiliser les canaux d'irrigation, en mentionnant spécialement les méthodes pouvant être utilisées lorsque le canal est sous eau.

L'eau dans le canal constitue un obstacle gênant pour la plupart des méthodes de revêtement; cependant, trois méthodes peuvent être utilisées dans ces conditions :

1) En faisant couler l'eau chargée de matériaux imperméabilisants. Exemples : Procédés par envasement et sédimentation.

2) En établissant un écran dans l'une ou dans les deux berges du canal. Exemples : Tranchées à la bentonite et injection de limon.

3) En plaçant un revêtement sous eau. Exemples : Filtre de gravier retenant le limon, couches d'argile posées légèrement, injection d'asphalte et des membranes préfabriquées d'asphalte (type exposé).

Les méthodes d'imperméabilisation des canaux d'irrigation sont généralement appliquées le canal étant à sec, et encore, sur une échelle relativement petite. Il s'ensuit que plusieurs des méthodes utilisées ne sont guère applicables sur des canaux de navigation. Des photographies relatives aux méthodes les plus usuelles sont jointes. Il en est de même des références bibliographiques qui ont trait aux méthodes conventionnelles.

En général, les méthodes normales peuvent être groupées en trois types :

1) Traitement du sol « in situ » par action obturante ou par additif.

2) Membrane enterrée en matériaux imperméables.

3) Revêtement en matériaux imperméables.

La majorité des canaux imperméabilisés aux Etats-Unis sont du dernier type, aménagés le canal étant à sec.

Dans le choix du type d'imperméabilisation de canaux d'irrigation, il faut tenir compte du fait qu'un revêtement n'est pas applicable dans tous les cas et que le coût de chacun varie d'après la nature du travail à exécuter. Il faut donc, pour atteindre un résultat satisfaisant, faire une analyse sérieuse des conditions dans lesquelles se trouve le canal et choisir judicieusement les matériaux imperméabilisants. Elle doit comprendre l'étude du coût d'entretien et de la durée probable du moyen à appliquer.
