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OPERATION AND MAINTENANCE EQUIPMENT AND PROCEDURES

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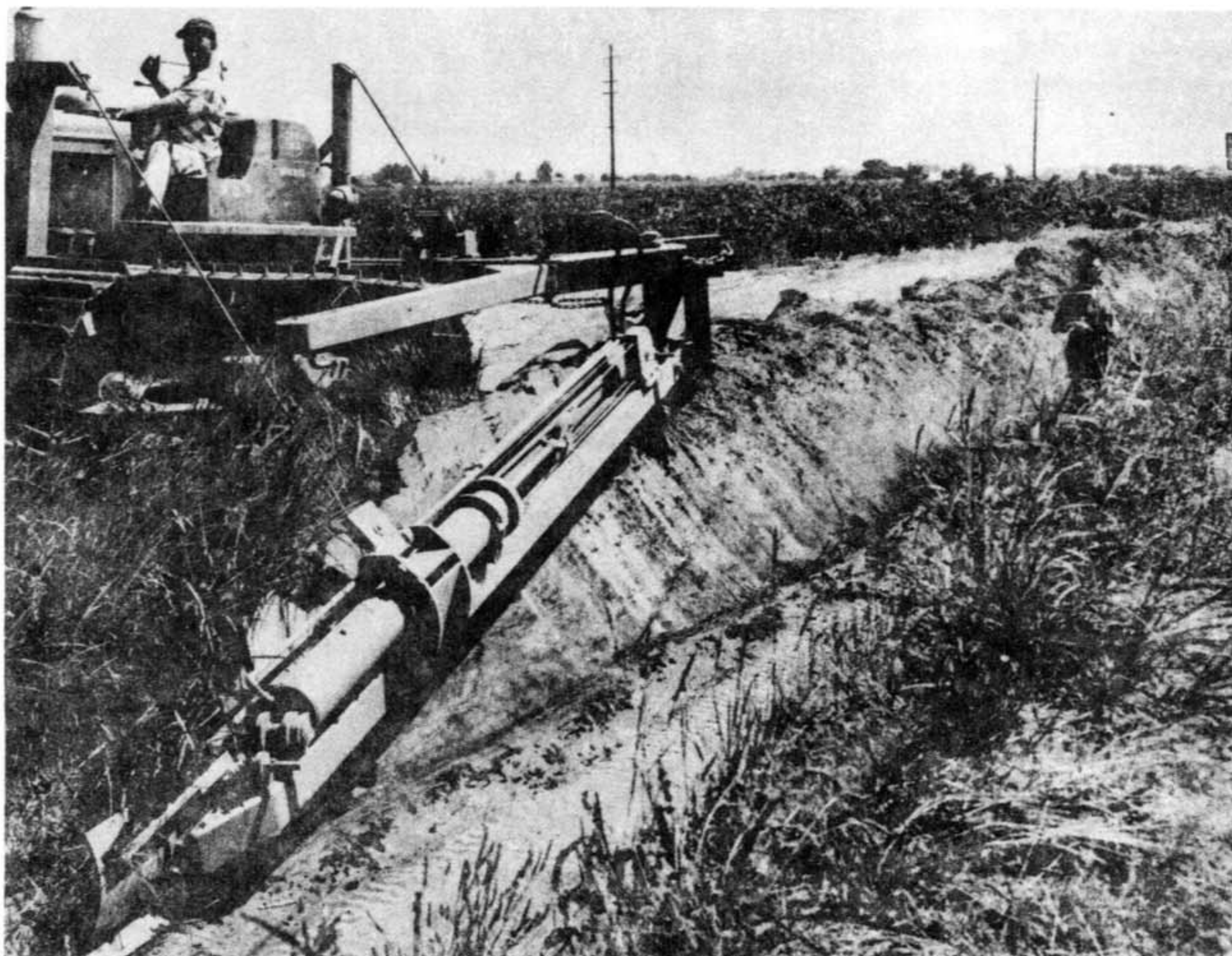

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INTRODUCTION

This release, Release No. 10 of the Operation and Maintenance Equipment and Procedures Bulletin, has been delayed in publication because of several uncontrollable circumstances, one of which was the assembly of information from the field.

The Bulletin is receiving wide distribution in the United States and Overseas and your contributions are being very well received. Recently our attention has been called to several worthwhile suggestions that were included in the Incentive Awards publication for which employees were recognized for making the suggestions. Several of these are included in this issue of the Bulletin, but the detail that makes this Bulletin more attractive is lacking in the award bulletin. In the future, it is suggested that material of interest to readers of this Bulletin also be forwarded to the Commissioner's Denver Office, Attention:- Code 400.

In a paper presented at the Annual Meeting of the National Reclamation Association last fall in Portland, Oregon, A. B. Reeves, Chief, Irrigations Operations Division, Bureau of Reclamation, Denver, Colorado, reviewed the Bureau's Lower-cost Canal Lining Program accomplishments. Mr. Reeves' paper is briefly summarized, beginning on page 6.

The O&M Equipment and Procedures Bulletin is circulated for the benefit of irrigation project operation and maintenance people. Its principal purpose is to serve as a medium of exchange of operating and maintenance information. Reference to a trade name does not constitute an endorsement of a particular product and omission of any commercially available item does not imply discrimination against any manufacturer. It is hoped that labor saving devices or less costly equipment developed by the resourceful water users will be a step toward commercial development of equipment for use on irrigation projects in continued effort to reduce costs and increase operating efficiency.

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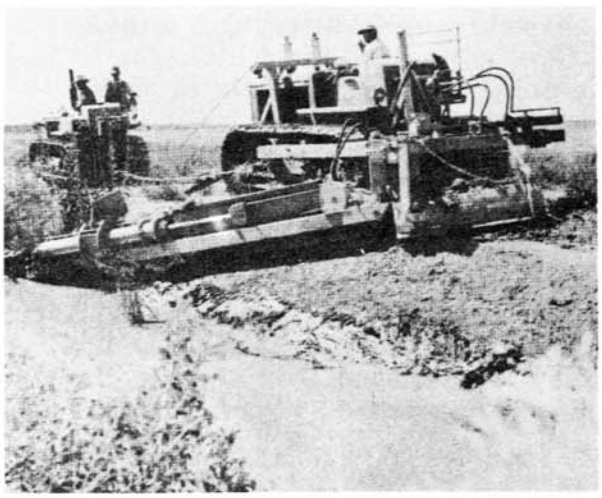
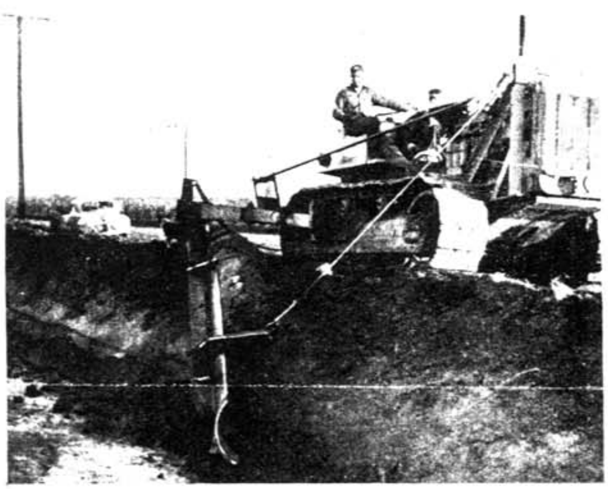
SLOPER SPEEDS CANAL BANK MAINTENANCE

Several projects have reported that the Briscoe Sloper is saving time and money in the maintenance of canal banks. Engineered primarily for the purpose of maintaining irrigation system canals, laterals and drains, and designed for mounting on several sizes and makes of tractors, the sloper is a welcome addition to any project's maintenance equipment.



The sloper is regularly furnished complete ready for mounting and includes a spoil wing which attaches to the rear of the tractor and spreads material brought up the slope. This reduces but does not eliminate the amount of work necessary to keep operating roads graded. The sloper can be operated with or without the spoil wing. It is important that the tractor have sufficient power for the work contemplated; the larger or deeper the canal, the larger the tractor needed.



Even in rough going, the sloper has been found excellent for the removal of weeds, silt berms, and in the general leveling of the bank slopes. The sloper operates efficiently with water in the canal, pulling the berms, grass, weeds, and debris to the top of the bank, where it will not float into and clog headgates or outlets. Where there are no obstructions, 3 miles of canal bank can be cleaned per hour. With obstructions, the progress is slower, but the blade can be quickly and easily swung up to pass over or around outlet headwalls, bridges, etc. with but a minimum of bank remaining to be cleaned by other means.

Further information regarding the cable controlled sloper shown in the lower photograph on this page, or the hydraulically operated one shown on the cover can be obtained from the manufacturer, E. V. Briscoe and Sons, Route 2, Box 118, Kerman, California, or by contacting distributors located in many cities.

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SILICONE RESINS AS WATERPROOFERS

Advertising literature has been received in which silicone resins have been described as useful in waterproofers for concrete, cinder blocks, wood, etc. Requests have been received by the Bureau's Denver Paint Laboratory from various branches within the Denver Office and from the field for information on the value of silicone resin for these purposes.

Conclusions drawn from the Denver Paint Laboratory research program in which these materials were evaluated indicated that the unpigmented silicone resins, in their present state of development, are unsatisfactory as waterproofers for below grade use and are unsatisfactory as waterproofers for uses where a hydrostatic head exists. It was further concluded that on porous surfaces, above grade, low solids content silicone resin based clear coatings could not be considered water repellents and thus would have little use in Bureau Construction.

These findings have now been confirmed by one of the producers of the silicone resins used by manufacturers of waterproofers. In literature describing one of their newest products in this field, they state that the resin can be used in the manufacture of coatings designed to "impart water repellancy to above-grade brick, concrete, mortar, cinder block, stucco, etc.".

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GLYPTAL SOLUTION PROLONGS LIFE OF TAGS

An employee suggestion by Robert E. Morris, Region 1, U. S. Bureau of Reclamation, saves time in making out safety and equipment marking tags. By dipping the tags in a 40 percent Glyptal solution, they remain legible for a longer period of time as well as being more durable.

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TURNTABLE ON MOTOR GRADERS LUBRICATED DURING OPERATION

A. H. Carlson, Region 1, U. S. Bureau of Reclamation, saves time and eliminates the need for a separate supply of lubricant in lubricating the circle (turntable) on motor graders during operation.

A 1/4-inch copper tubing is run from a shut-off valve connected to a fuel tank to a control valve inside the grader cab. The tubing is continued from the control valve along the frame to the front of the drawbar. At that point a short length of flexible tubing is connected to copper tubing leading back along the drawbar to the circle. Using the control valve, the operator can clean and lubricate the circle from the cab while the grader is in motion.

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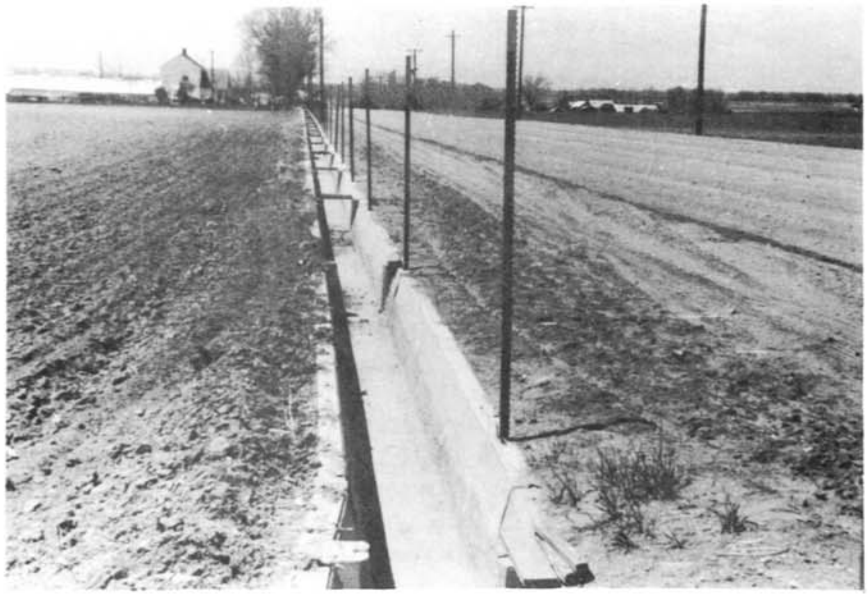
CONCRETE LINED FARM DITCHES

In water short areas of North-eastern Colorado, the farmers are attempting to conserve every possible drop of irrigation water by the installation of concrete linings in their farm ditches. Construction varies, but for the most part, like those shown below, they are cast-in-place linings, utilizing ready-mixed concrete wherever a ready-mix plant is in the close vicinity. The linings are unreinforced.

The lining above has a bottom width of 18 inches and a 10-inch depth. Instead of providing outlets in the lining, 6-inch siphon tubes are used to get water to the land.

The above lining has a 13-inch base width and 12-inch depth. Reusable forms were employed and at frequent locations a section of lining was placed having grooves for the installation of check boards.



Full advantage has been taken by the installation of the above lining to cultivate and irrigate all possible land in the field. Located along the fence line, the steel fence posts have been set in the concrete of one side of the lining.

Concrete lining from an abandoned ditch has been salvaged and is being replaced in a new ditch. The unreinforced concrete lining withstood the handling very well.

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A REPORT ON THE LOWER-COST CANAL LINING PROGRAM

In a paper presented at the annual meeting of the National Reclamation Association in Portland, Oregon, November 8-10, 1954, A. B. Reeves, Chief, Irrigation Operations Division, Bureau of Reclamation, reviewed the Bureau of Reclamation's Lower-cost Canal Lining Program. The accomplishments of the program since its inception in 1946, the advantages and limitations of various types of linings, and the future investigations planned were discussed. Copies of Mr. Reeves' paper, "Linings for Irrigation Canals", may be obtained by writing the Commissioner's Denver Office, U. S. Bureau of Reclamation, Denver Federal Center, Denver, Colorado, Attention:- Code 400.

Approximately 26, 000, 000 square yards of lower-cost linings have been placed in more than 750 miles of canal and laterals on Bureau Projects since 1946. The table on the following page is a summary of the various type of linings placed and their representative cost. The cost of a lining to meet a given condition will vary with the individual job.

Selection of a Lining

No one lining is satisfactory for all conditions to be encountered. Selection of a lining to meet given conditions was discussed by Mr. Reeves and a summary of his remarks follow.

Canal Linings are Expensive

Even the lower-cost canal linings are expensive. In good terrain, a lined canal will generally have first costs 2 to 3 times that of an equivalent unlined earth canal because of the cost of the lining. The costs presented on the following table, with few exceptions, are representative installation costs for the various types of linings placed under contract by the Bureau of Reclamation. The exceptions are for experimental installations made by contractors or by Government forces and reflect the cut-and-try costs associated with this type of work.

In the selection of a lining, the location of the canal or lateral, the character of the subgrade and construction materials available, and the cost of maintenance and probable useful life must be considered. Accurate maintenance costs are difficult to obtain and in many instances the probable useful life must be estimated, as few experimental linings have been in use more than six to 8 years.

Concrete Linings

The tabulation does not include the more costly reinforced concrete linings. In general, they are now used only where structural safety is imperative or where other factors such as frost action, high hydrostatic pressure, etc., must be considered. There is no reason to believe that reinforced concrete will outlast unreinforced concrete, if the latter is properly designed, constructed and selected for a suitable location.

CANAL LININGS PLACED
and their
REPRESENTATIVE COST

(Since December 31, 1946)

	Lining Placed Sq. Yds.	Lining Placed Miles	Installed Cost per Sq. Yd.
Unreinforced Concrete	17,406,210	389.0	
3 to 4 inches in thickness			$2.50
$1\frac{1}{2}$ to 2 inches in thickness			1.30
Shotcrete Linings	1,054,221	115.6	
$1\frac{1}{2}$ inches in thickness			2.00
2 inches in thickness			2.30
Asphalt:-			
Asphaltic Concrete	228,416	31.9	2.40
Buried Asphaltic Membranes:			
Hot-applied (sprayed)	2,152,391	102.3	1.14
Light prefabricated	15,376	1.2	1.50
Exposed, heavy asphaltic membrane	3,434	0.5	1.54
Asphalt Macadam	3,500	0.1	*
Prime asphalt membrane	13,591	1.8	*
Earth:-			
Heavy compacted	4,176,235	72.0	
Large Canal.			0.55
Small canal or lateral			1.00
Thin Compacted	131,519	5.9	0.40
Loosely placed earth blankets . . .	351,146	19.1	0.24
Silted or sediment lined	**	**	0.14
Bentonite:-			
Raw or processed membrane . .	123,282	9.5	1.01
Bentonite-soil mixture	6,080	0.8	1.60
Mixed-in-place	24,664	1.8	*
Soil-Cement:-			
Standard type	69,020	8.0	0.76
Plastic type	10,018	1.1	0.89
Miscellaneous . . . . (Includes grouting, asphalt under-sealing, asphalt emulsion concrete, asphalt emulsion-mortar shotcrete, etc.)	22,399	2.5	*
Total	25,791,502	763.1	

*The small amount of lining installed on an experimental basis
**Not applicable.

Again with reference to the tabulation, the lower-cost concrete linings are first in volume placed since 1946. These linings can be included in the lower-cost category because of improved techniques in placement, liberalization and simplification of specifications, elimination of reinforcement steel, development of subgrade-guided slip-forms, and standardization of canal shapes and sizes.

Even the lower-cost concrete linings are higher in first cost than many other types of canal linings, but they are probably lower in maintenance cost and longest in useful life; that is they are longest in useful life from the point of experience. We do not have comparable records of useful life for other types of linings.

Concrete is more resistant to erosion than most other types of linings and because of its beam strength, it will usually bridge short reaches of poor subgrade support. Therefore, it is preferable where high velocities exist or where safety is of primary importance. Concrete linings eliminate weed growth and burrowing animals cannot penetrate the lining as they can unlined or earth-lined canals; hence, lower maintenance costs.

Failures of concrete linings are generally due to adverse subgrade conditions, excessive hydrostatic pressures beneath the lining, frost heaving, poor quality concrete, faulty design or construction, etc. In northern climates, frost heaving is the greatest factor contributing to the destruction of concrete linings.

Shotcrete Linings

Shotcrete (pneumatically applied portland cement mortar) continues to be successfully used in the Southwest, where the climate is not severe. It can be placed on irregular surfaces obviating the necessity for fine trimming of the subgrade prior to application. It has been used satisfactorily for resurfacing badly cracked and leaky, but reasonably sound old concrete linings.

Although many miles of shotcrete linings have given years of satisfactory service, particularly in the southwestern states, in general, it is not considered as desirable or as economical as slip-formed concrete linings for large jobs. Not only is the rate of placement for shotcrete lining very slow in comparison to slip-form operations, but shotcrete $1\frac{1}{2}$ inches in thickness usually costs as much as 2 inches of concrete, if conditions are favorable for slip-form placement.

Asphaltic Concrete

A combination of asphaltic cement and aggregate; mixed, placed and compacted in a hot and plastic state, asphaltic concrete is most satisfactorily placed by slip-forms of the subgrade guided type because of the resulting economy and uniform high density. This lining is particularly well adapted to smaller canals and laterals, although it has been used for larger facilities.

Since no curing is required, the lining is ready for immediate use after placement and cooling.

The cost of asphaltic concrete lining is comparable with that of slip-formed concrete lining and offers a saving in installation cost only where suitable concrete aggregates are not available. Because of the plastic nature of this lining, some types of weed will penetrate it. In fact, weed growth is actually promoted by the heat absorbing property of the black surface. Treating of the subgrade prior to placement of the lining is advisable, especially when it is placed in areas where such weeds as tules, cattails, or willows are firmly rooted. A harder asphalt is now specified for use in hot-mix asphaltic linings today, to obtain better resistance to water erosion and weed puncture.

Buried Asphaltic Membranes

Two types of buried asphaltic membrane linings have been used to good advantage in Bureau construction. One is composed of hot asphalt cement applied directly to the subgrade and the other is a prefabricated material similar to rolled roofing which is laid upon the subgrade.

Buried Hot-Applied Asphaltic Membranes

Essentially, the hot-applied buried asphaltic membrane lining is one in which the asphalt layer, 1/4- to 3/8-inch in thickness, is sprayed upon the subgrade, and this barrier to the passage of water is held in place and protected against injury and weathering by covering with a layer of earth and/or gravel. A special catalytically blown asphaltic cement is now used for the membrane, and has been found to be superior to other types of asphalts.

This type of lining is third in volume installed on Bureau projects since 1946. Availability of suitable asphalt throughout the western states has contributed to the extensive use of this lining, which can be placed at costs less than half that of most hard surface linings. The lining can be installed in much less time that a hard surface lining with a minimum of interference to regular operations, and also can be satisfactorily installed in cold or wet weather, frequently encountered during the non-operating season in northern climates.

The maintenance of asphaltic membrane linings is slightly more than that for an unlined canal. The soil or gravel cover over the membrane is subject to beaching and weed growth in much the same manner as earth lined or unlined canals, and the membrane must be kept covered at all times.

As for useful life, it is believed it is a matter of how long the membrane will last. Recent tests of the membranes indicate very little deterioration with age, and good service is expected.

Buried, Lightweight, Prefabricated Asphaltic Membranes

Prefabricated asphaltic membrane linings were developed to permit use of an asphalt membrane, but to eliminate the use of hot asphalt requiring skilled personnel and special equipment for placement. The lightweight prefabricated linings resemble and are handled and placed in much the same manner as rolled roofing; lapping and cementing the joints. These linings also must be protected from damage by a cover or earth and/or gravel, and maintenance problems are similar to those of the hot-applied buried membranes.

Because of the hand labor involved in placement, the prefabricated membrane is more costly to install than the hot-applied membrane, but is particularly adapted for placement in remote locations and by maintenance forces, where the amount of lining required is not great.

Exposed, Heavy, Prefabricated Asphaltic Membrane

To eliminate the need for a protective cover over the prefabricated membrane, several manufacturers have now developed a thicker, heavier type of material, 1/4- to 1-inch in thickness, which we term "Heavy, Prefabricated Membrane". Several trial installations have been made on small laterals, and the cost for installation will vary with the thickness of the material used.

Asphalt Macadam

Asphalt macadam has been used only in a limited way in Bureau work. Few macadam linings have been constructed, but it has been used as a cover material for other types of linings quite successfully, primarily where suitable cover material of other types is scarce or obtainable only at high cost.

Prime Asphalt Membranes

Prime asphalt membrane linings were the forerunners and led to the development of the hot-applied, buried asphaltic membranes. Few of the prime membrane linings have withstood the test of service or exposure. More recently, prime membranes have been considered for use in stabilizing sandy soils, rather than making them water-tight.

Heavy Compacted-Earth

The second largest volume of lining placed by the Bureau has been heavy compacted-earth. It might more appropriately be called "thick, compacted-earth lining", as compared with the thin, compacted-earth linings discussed below. Constructed of selected impervious soils, placed with the bottom and side slopes compacted in horizontal layers 6 inches in thickness, the lining thickness is about 3 feet on the side slopes (with the thickness measured normal to the slope) and 2 feet on the bottom.

Where suitable material is available with a minimum of haul and the job is large enough to utilize mechanized equipment fully, this lining has proved to be one of the lowest in first cost. Because of the high uniform density, stability, and thickness a protective cover is not required, except at curves or other points of high water-velocity.

Properly constructed, the lining has been found by field tests to be highly impermeable; with losses comparable to those of a good concrete lining. In areas where high ground water or expansive soils predominate, heavy compacted-earth linings may be preferred to concrete linings. The rigid concrete linings have been disrupted by the expansion on wetting of expansive subgrade soils or by hydrostatic pressures from a high ground water table; whereas, the compacted-earth linings, characterized by greater weight and flexibility, are not ordinarily damaged by these forces.

Maintenance of compacted-earth linings should be about the same as an unlined canal. We have only meagre information concerning the useful life of these linings, but one lining in a northern project has been performing well for a period of 13 years, with recent tests indicating it has been little affected. Linings installed more recently are now being examined.

Heavy compacted-earth linings appear more suitable for the larger canals; however, some adaptations have been attempted for smaller facilities. A narrower lining having a horizontal width of only 3 to 4 feet, as compared with the 7 to 8 feet in the larger canals, has been placed using smaller equipment; compacting with a single sheepsfoot roller pulled by a small crawler or farm type tractor. Another lining was placed in a small lateral by first filling the canal prism with compacted-earth and later reexcavating with a plow-type ditcher.

Thin, Compacted-earth linings

Thin, compacted-earth linings ordinarily 6 to 12 inches in thickness and composed of cohesive soil thoroughly compacted and protected by a coarser soil or gravel have been used considerably in the past. Recently, the Bureau has not employed the thin-compacted earth linings on a large scale, because of the relatively high cost of side slope compaction.

These linings should have maintenance costs comparable with other types of earth linings if adequately protected from damage by erosion or during cleaning operations.

Loosely Placed Earth Linings

Probably the most widely used of all in the past, is the loose earth lining which consists of a blanket of soil cast on the subgrade of a canal or lateral or pushed into place by mechanical means or by hand. Generally, they are not as effective or as permanent as compacted-earth linings and are used very little by the Bureau except in case of emergency.

Little trimming or reshaping of an existing canal is necessary and equipment requirements are exceptionally simple. Seepage has been effectively and economically reduced only if the blanketing soils are impervious in a loose state and are adequately stable to resist erosion. Soils containing sand and gravel have been placed on some Bureau projects in this manner and are performing well. Low first cost of lining makes use of the loosely placed earth blanket attractive, but maintenance may be high, if erosion is to be controlled.

Sediment Linings or Silted Canals

The deposition or relatively thin layers of clay or silt over the wetted perimeter of an unlined canal usually reduces seepage significantly. This may be a natural process if the flowing water carries sediment, or a sediment may be added. The effectiveness of the sediment lining is dependent upon the material used, the velocity of the water in the canal, and the structural formation of the subgrade material through which the seepage occurs.

These linings are highly susceptible to erosion, puncture, deterioration by weathering, and destruction during cleaning operations. Experience in the field has shown that unless it is possible to secure penetration of the sediment into the voids of the subgrade material, linings of this type will have a very short life. Except for the fact that they are low in first cost and the treatment can be repeated from time to time with little additional cost, the linings as such have been very ineffective over a period of time. Repeated treatment increases the amount of cleaning that is necessary and therefore increases the cost of maintenance.

Bentonite Linings

Bentonite is an earth material containing a large percentage of montmorillonite-type clay. It is characterized by high water absorption, accompanied by swelling and imperviousness. This characteristic has made it useful as a canal lining material, where a good quality bentonite is available at reasonable cost. Bentonite has been used as a buried membrane; by pre-mixing it with soil to form a 2- to 3-inch thick impermeable layer, usually compacted into place; and by mixing it in place with the subgrade materials.

Bentonite Membranes

As a membrane, bentonite has been very effective in reducing seepage losses. Like asphaltic membranes, it is believed these installations will prove effective as long as the membrane is protected from drying out, weathering, and erosion. Protection usually consists of a loose cover of earth and/or gravel. One of the oldest bentonite membranes has been in service for 13 years. The bentonite used has been raw pit run or commercially ground and dried material.

Bentonite-soil Mixtures

Either pit run or commercial grades of bentonite may be mixed with soil and both have been very effective over a period of several years in providing water tightness to canals and laterals. The optimum amount of bentonite to be used with a particular soil must be determined by laboratory tests. Essentially, the bentonite is a filler or binder for coarser silty and sandy soils, which alone would neither be stable nor water-tight. Usually, placed as a 3- to 4-inch thick layer, it is recommended that a protective cover of stable earth or gravel be placed over the lining.

This type of bentonite lining is generally more costly than the membrane, due to compaction on the side slopes. Maintenance costs should be about the same as for other types of earth linings.

Mixed-in-place bentonite-soil mixtures

Mixing bentonite with the subgrade materials by spreading it over and plowing or discing it into the subgrade material to depths of 6 to 12 inches has been effective in reducing seepage through the bottoms of canals and laterals. It is difficult to place and mix in this manner on the side slopes with existing equipment and hand placement is costly. After mixing, the subgrade should be compacted to reduce the possibility of erosion.

Soil-Cement

Soil-cement has been used as a canal lining material in localities where subgrade soils or those adjacent to the canal are of a sandy character and suitable earth materials are not readily available. Installation costs in trial installation have been relatively low. Two types of soil-cement have been used; the standard type and the plastic type. Few soil-cement linings have been placed in recent years although performance has been reasonably satisfactory in some locations in the southwest.

Standard Type

Standard soil-cement is a compacted mixture of soil and cement in which the moisture content of the mixture is maintained at time of placement at about the optimum as determined by laboratory compaction tests. Mixing has been accomplished by discing and blading the mixture into place, but it is best accomplished by use of a pulvimixer. The spreading and necessary compaction on canal side slopes as steep as $1\frac{1}{2}$ or 2 to 1, is difficult to accomplish, and early deterioration of the lining on the side slopes is believed due to lack of density. An installation in which a special compaction machine was used in a small lateral was made this past winter. The cement companies and the Portland Cement Association also collaborated in this installation.

Plastic Type

Plastic soil-cement having a higher water content than that of the standard type, and a consistency comparable to concrete may be placed by means of a slip-form similar to that utilized in the placement of concrete linings. This overcomes the difficult slope compaction of the standard type soil-cement. The plastic linings, however, exhibit low resistance to weathering and erosion.

Experimental Linings and Related Studies

The linings discussed above are for the most part either those tried and approved for construction or abandoned because of inferior results or excessive installation or maintenance costs. Renewed interest in some of the linings is possible because of improved techniques or the development of better methods and equipment for placement. In addition, the Lower-cost Canal Lining Program continues to foster studies of other materials and methods for use in the lining, stabilization and waterproofing of canal subgrade materials and perform related studies. Some of the studies underway which have not been advanced sufficiently for general field application are described below.

Physical Stabilization and Compaction of Subgrade Soils

Some subgrade materials can be made sufficiently dense by compaction alone to improve their impermeability. Also the suitability of either clayey or granular soils may be improved and the impermeability increased by combining them in proper proportions in the placement of a thin or heavy compacted-earth lining. Just recently, this latter has been attempted on a large canal. It offers possibilities at reasonable cost only if a large amount of lining is required, and where large mechanized equipment can be used.

Resin and Chemical Stabilization

Resins and chemicals have been used in roadway construction for stabilization and waterproofing. They have also been used experimentally in canal linings. However, further study is necessary before field application can be made. Some chemicals are toxic and in leaching tests the waters have also been found to be toxic.

Bentonite Sedimenting

Being a very fine colloidal material when mixed with water, some bentonites can be kept in suspension in waters flowing within a canal. It is reasonable to assume that with the particles kept in suspension, water seeping from the canal will carry the suspended bentonite into the voids of the canal subgrade materials. If it is possible to fill the voids of this subgrade material with the colloidal clay to a sufficient depth to prevent its eventual erosion, it will provide an impermeable barrier to the passage of water.

This study is a continuation of the general study of silting and sediment lining. Bentonite is being used as the sedimenting material because of its very fine colloidal characteristics and general chemical uniformity. Our present study is directed toward (1) securing stable suspensions of the colloids in given canal waters, the chemical nature of which affects this stability; (2) determining the depth to which the colloids penetrate the voids of various types of subgrade materials; (3) making limited field demonstrations under controlled conditions; and (4) determining the permanence of the field treatment in providing impermeability to a given subgrade material.

Although there is existing literature on the subject to the contrary, it is emphasized that the permanence of the method has not been proven. From three installations made this past spring, there is an indication that seepage has been reduced considerably in a sandy soil, some limited benefits with a loess, and little benefit in fractured bedrock. This leads to the conclusion that in very fine grained soils, in very coarse grained soils, and in large fissures and cracks, the bentonite has either not penetrated or has passed on through the void space.

There are other problems in using bentonites that make further study necessary. There are high-swelling and low-swelling bentonites. The character of the particular bentonite, the chemical composition of the canal water and that of the subgrade material must be known. The incompatability of the chemical composition of these materials can result in flocculation of the bentonite and result in its settling out of the canal water within a very short distance; benefitting only this short reach and forming a thin coating which is easily eroded.

Other Types of Asphaltic Canal Linings

The variety of asphalt mixtures, their combination with other materials, and their method of use have led to other developments in the treating of canals and laterals to secure imperviousness, stability, and waterproofing. The asphalt producers have cooperated in the application of their products to the Lower-cost Canal Lining Program. Some of the newer applications to the problems, or some that have not found wide usage to date are asphalt emulsions; pneumatically applied asphalt, sand, and cement mixes; prime asphalt stabilizers; and the injection or grouting of canal materials with asphalt.

Asphalt Emulsion

The cold-mix asphalt emulsions have been used in a manner similar to hot-mix asphalts in concretes, with the aggregate and asphalts being thoroughly mixed and compacted in place. These linings require curing, which in turn requires time and favorable weather conditions. Some of the mixes remained soft and others contracted upon drying and curing, thereby creating cracks that must be filled. Cold mixes so far placed exhibit low resistance to erosion and lack stability for an appreciable length of time. The addition of a filler and portland cement to overcome this deficiency has been tried.

Pneumatically Applied Asphalt Mixtures

Several experimental linings have been constructed in the manner of portland cement shotcrete linings. The pneumatic method of placement is particularly advantageous in covering exceptionally rough surfaces, but the slow rate of application, cost, and low resistance to erosion and weathering have so far been unfavorable for its wide use. The addition of portland cement to the mixture has added stability and provided for additional resistance to erosion.

Undersealing of Old Concrete Canal Linings

Although not strictly a lining in itself, the undersealing of old concrete linings by forcing hot asphaltic cement under the lining has been successful in preserving the original concrete lining in several locations. This is not a new process, but recent techniques have provided for better results.

Plastic Linings

Canal linings of synthetic plastic are under consideration. A number of manufacturers have furnished samples of their products for laboratory testing and field installations. Presumably, the plastic lining would be of the buried membrane type, covered with earth and gravel for protection, although field experiments with plastics of greater thickness have been made in which the plastic is used as an exposed lining. In the past the cost of the plastics has made their use prohibitive. Lower material costs are promised by the manufacturers.

Monolithically Cast-in-place Concrete Pipe

Included in the Lower-cost Canal Lining Program because it replaces a lined canal, monolithically cast-in-place concrete pipe was installed experimentally during the past year. This type of pipe has been previously used by private irrigators in California and has a record of serviceability. Its cost, compared to the placement of some types of linings has been high and this has been one reason it has not been previously considered. Its structural strength has been another factor.

The pipe has been used primarily to replace small laterals and lateral distribution systems having hydrostatic heads up to about 8 feet maximum. The recent installation made will provide additional information regarding serviceability and cost. Preliminary data indicates the pipe to be competitive with precast pipe in the smaller sizes and with concrete linings.

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