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LINING IRRIGATION LATERALS AND FARM DITCHES

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LINING
IRRIGATION LATERALS and FARM DITCHES

By C. W. Lauritzen, *soil scientist, Soil and Water Conservation Research Division, Agricultural Research Service*

Water is becoming one of the Nation's most limiting resources. In irrigation for agriculture, conveyance losses and low application efficiencies of water represent the principal source of waste. About one-third of all water diverted for irrigation is lost from point of diversion to the farm. Another third is lost through deep percolation and runoff during application. This leaves one-third of the water diverted for irrigation available for plant growth and land conditioning.

Both conveyance and application efficiencies of irrigation water can be greatly improved. Conveyance losses are easier to control, as canal management is usually in the hands of trained people. Watertight conveyance structures almost completely eliminated losses. Closed underground conduits are more efficient than open channels, but in most instances conduits are more expensive to construct than channels. Linings also help to control weeds and indirectly contribute to the solution of the drainage problem.

Before the lining of any ditch is undertaken, careful consideration should be given to location. If some relocation would contribute to better operation of the irrigation system, the ditch should be relocated before it is lined. Usually it is less expensive to construct a new ditch than to prepare an old one for lining. The lining is the expensive part of the job. All ditches should be so designed that they will deliver safely and efficiently the desired amount of water to the land they serve. Furthermore, provision must be made for diverting the water onto the land to be irrigated.

Preparation of Channels for Linings

An important operation in the construction of a channel lining is the preparation of the subgrade, or invert. All vegetation and debris should be removed from the site by scraper or other land-clearing equipment. Trees and brush along the sides and grass and other vegetation, including the roots, on the banks of existing laterals and ditches should be removed. Generally, the cross section of an unlined canal is larger than that required after lining; the space between the lining and bank is reduced by backfilling. To provide a satisfactory base for a lining, the backfill material should be free from vegetation and should be placed in the invert and compacted in layers not to exceed 6 inches.

Where linings are to be placed with subgrade-guided slip forms, a pad is usually constructed first. The pad is constructed in much the same manner as that used in roadbed construction and includes the making of cuts and fills and compacting the material as it is placed. The surface of the pad should be twice the width of the canal. The surface should be smooth and the grade should correspond to the design grade of the finished canal (fig. 1).

Extreme care is necessary in opening and shaping the lateral or ditch to receive the lining. This is especially true when linings are placed with subgrade-guided slip forms, since the lining will have essentially the same grade and alinement as the invert. Careful staking is essential. This will probably require the services of an engineer or

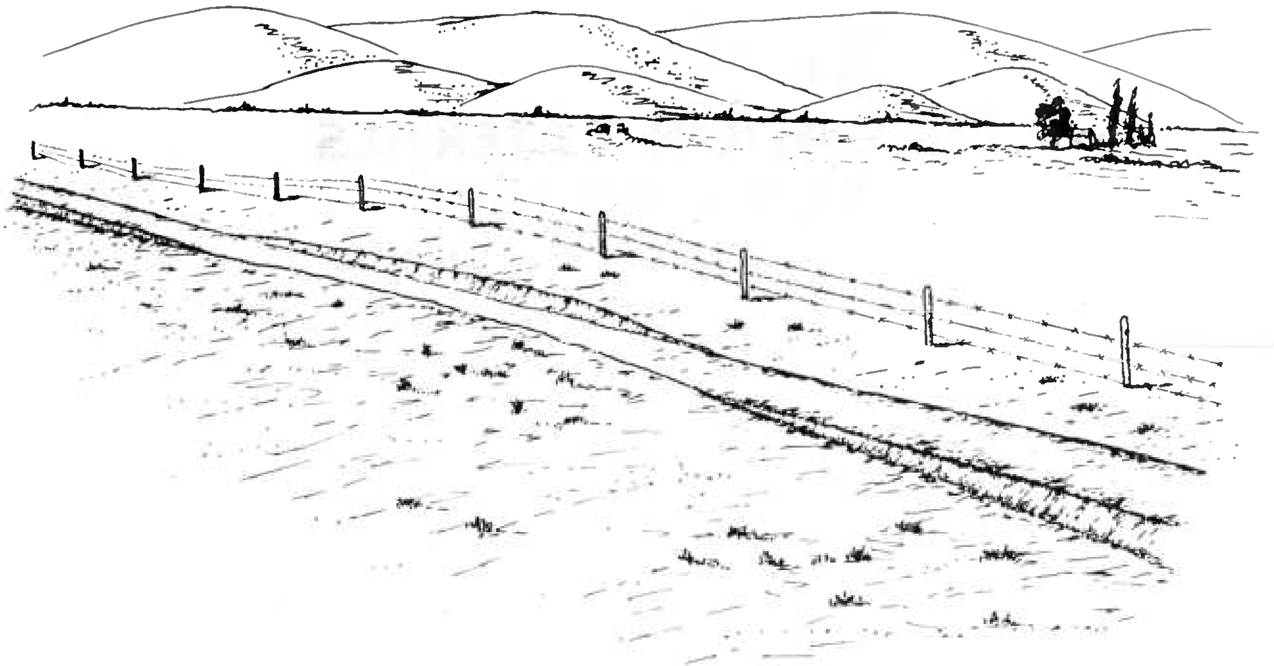

FIGURE 1.—Pad ready for excavation and lining of a field ditch with slip form.

someone capable of setting stakes for line and grade. The services of Soil Conservation Service engineers are usually available. Separate operations for excavating the ditch and placing the lining are usually preferable.

As an aid in grade control, stakes are sometimes set along the center line at the exact elevation after the ditch has been excavated to its approximate depth. To set the stakes, a hole is dug with a shovel in the bottom of the ditch so that the top of the stake can be set to grade. The distance between stakes depends on the location of the work and the experience of the operator digging the channel. Usually the distance between stakes is 50 to 100 feet. Successive passes with the plow are made until the bottom of the ditch is exactly even with the top of the stakes. Between each pass the tops of the stakes are uncovered. For best results the elevation on the bottom of the ditch should be checked with an instrument during the process of construction.

Opening of the ditch and preparation of the subgrade are extremely important; if these jobs are not done properly, the lining will not be satisfactory.

A backhoe or a V-plow is the equipment usually used to excavate irrigation laterals and ditches. If a backhoe is used and the bucket has the same dimensions as the ditch, less hand trimming will be required. A machine of the Gradall-type (fig. 2, *A*)

FIGURE 2.—*A*, A Gradall excavating a small lateral; *B*, plow used to excavate field ditch in preparation for lining with slip-formed concrete.

does a faster and better job of excavation than a backhoe, because it is easier to control the shape and alinement of the ditch. To do a satisfactory job with a plow (fig. 2, *B*), the tractor should be fitted with controls that can regulate the cut and alinement of the ditch. Regardless of the implement used for excavation, the ditch should be smooth, firm, and free of all loose material before it is lined. Even then, some handwork will be required on most jobs if deviations from line and grade are to be held within reasonable limits. Deviations from the horizontal and vertical alinement of 0.3 and 0.1 foot, respectively, can be considered acceptable.

Lining Materials

The two most important materials for lining channels are portland cement concrete and asphalt. Compacted earth is sometimes used, and some experiments have been conducted with butyl rubber sheeting and plastic film liners.

Until recently, only portland cement concrete was well adapted to farm ditches and small intermittently used laterals. About 1955, prefabricated asphaltic liners were developed that offer possibilities as ditch liners.

The choice of lining for a particular job will depend primarily on construction costs. In areas where good concrete aggregate is available locally, slip-form-placed portland cement concrete is probably the most economical lining. However, in those areas where concrete aggregate is not available locally, the cost of concrete linings may be prohibitive and asphalt linings would probably be a better choice.

Although not seriously damaged by occasional livestock crossing, exposed asphalt linings are not recommended for areas subjected to considerable traffic. Also, care will have to be exercised in cleaning asphalt linings. On the other hand, concrete linings may be damaged during freezing weather if they are installed in areas where the moisture in the ground water table comes in contact with the lining. They are also subject to damage when the foundation material consists of a clay or bentonitic material that swells when wet and shrinks and cracks when dry.

Asphalt linings are not corroded by sulfates and might be considered in the place of concrete in areas where high concentrations of sulfates are known to be a problem. The use of type V cement in the construction of concrete linings will greatly reduce the sulfate attack and partially overcome the advantage that may otherwise favor the use of asphalt linings in these areas.

CONCRETE LININGS

Portland cement concrete is one of the most widely used construction materials and is recognized for its durability. If linings of concrete are to be durable, the concrete mix must be properly designed and the mix placed and cured in accordance with good construction practices.

There is some question about the value of high-strength concrete, especially in linings for field ditches that would have a bottom width of 1 to 1½ feet and a top width of 3 to 6 feet. A compressive strength of 3,000 pounds per square inch in 28 days, however, is frequently specified. This strength can be obtained from average concrete materials, if not more than 5½ to 6 gallons of water are used for each 94-pound sack of cement. Only air-entrained concrete mixtures should be used. When available, air-entrained portland cement is easier to use. If air-entrained cement is not used, an air-entraining agent should be added to the concrete mix with the water in sufficient quantities to entrain approximately 6 percent air by volume. The mix should be readily workable but of such consistency that water will not segregate on the surface.

For small ditches having a bottom width of less than 2 feet and a depth of 3 feet, a 6-bag plant mix is usually satisfactory. The composition of this mix will vary with the aggregate used, but where the aggregate consists of medium sand and a coarse aggregate with 1½-inch maximum size, it is approximately as follows:

Material:	*Quantity*
Cement	1 sack
Water	5½ gallons
Sand	180 pounds
Coarse aggregate	340 pounds

Detailed information on the design of mixes is contained in a bulletin by the Portland Cement Association.[1]

For slip-formed or panel-constructed linings, the mix should have a slump of about 3 inches as determined with a slump cone.[1]

Unless the earth material in the channel is naturally moist, the invert should be sprinkled before placing the concrete lining. Dry soil will extract moisture from the concrete and thus impair the quality of the lining structure.

After the fresh concrete is in place, it is sprayed with a curing compound to prevent evaporation of the water in the mix until hydration can take place. Proper curing could be accomplished by keeping the concrete continuously wet, but it is usually more expensive to keep the concrete wet than to use a curing compound.

Slip-Formed Linings

A slip form may be used to place concrete linings in ditches (fig. 3). The front part of the subgrade-guided slip form rides on and is guided by the subgrade as it is pulled forward. A tractor or a winch mounted on the slip form, with the cable attached to a deadman, may be used to pull the form. The middle section of the slip form is the hopper through which the freshly mixed concrete is poured and then distributed by the form to the sides and bottom of the invert. The rear section of the slip form is the strikeoff, or screeding, mechanism. The difference in height between the bottom of the rear section and the bottom of the front section determines the thickness of the concrete lining (fig. 4). Since the slip form is guided by the subgrade, the lining will have essentially the same grade and alinement as the invert before lining. Slip forms are sometimes built by contractors and farmers. The forms are also available from at least one commercial source. Although slip forms vary, two designs that are fairly satisfactory are illustrated in figures 5 and 6.

When a slip form is in use, concrete should be available in sufficient volume so that the form can be in operation as continuously as possible. Commonly, the wet concrete is supplied to the form with a fleet of "ready mix" trucks.

Immediately after the lining is placed on the subgrade, weakened plane joints should be constructed (fig. 7). If the lining is 2 inches thick, the joints should be 6 feet apart; if the lining is 3 inches thick, joints should be 10 feet apart. The grooves are cut one-third the thickness of the lining (that is, ⅔ inch and 1 inch, respectively, for 2- and 3-inch linings). This depth insures that cracking

[1] "Design and Control of Concrete Mixtures," which is available free upon request from the Portland Cement Association, 33 West Grand Avenue, Chicago 10, Ill.

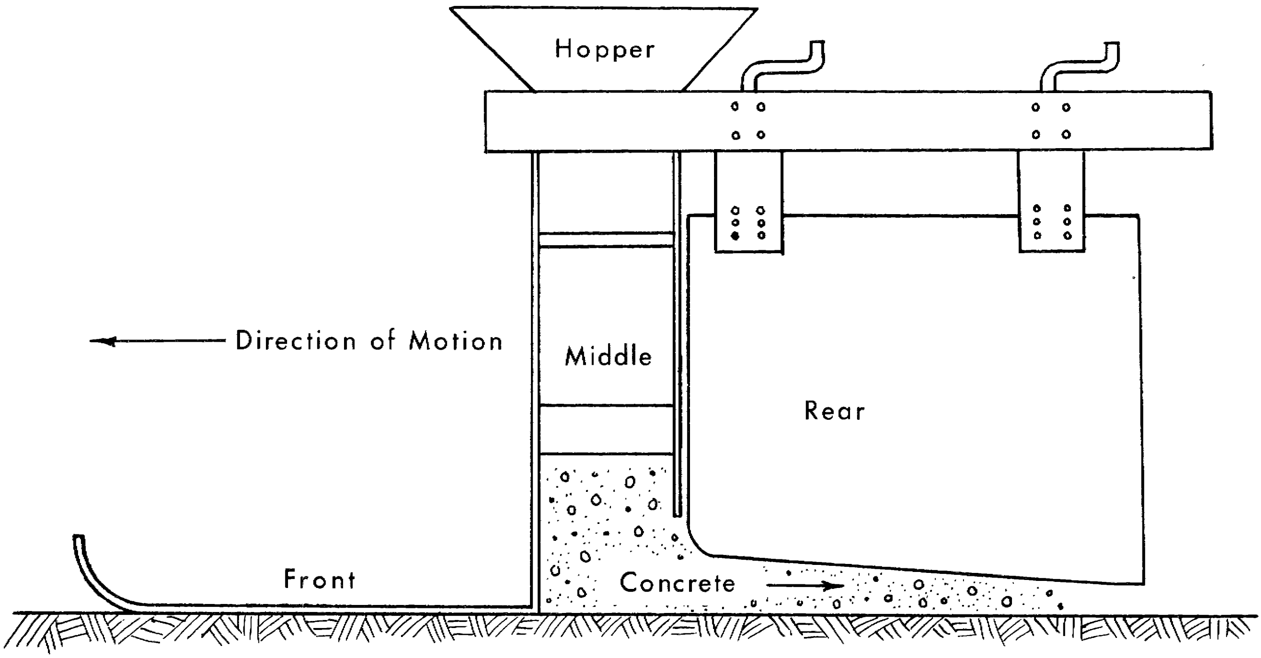

FIGURE 3.—Sketch of a form used to construct slip-formed linings.

FIGURE 4.—Front end of slip form, showing winch and cable attached to anchor ahead for advancing slip form.

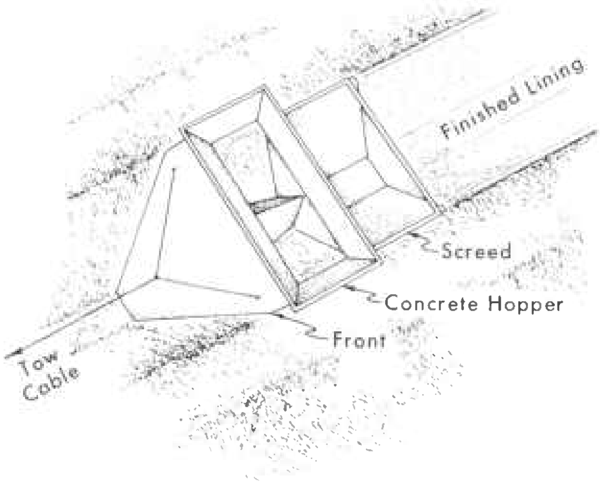

FIGURE 5.—Diagrammatic features of subgrade-guided slip form.

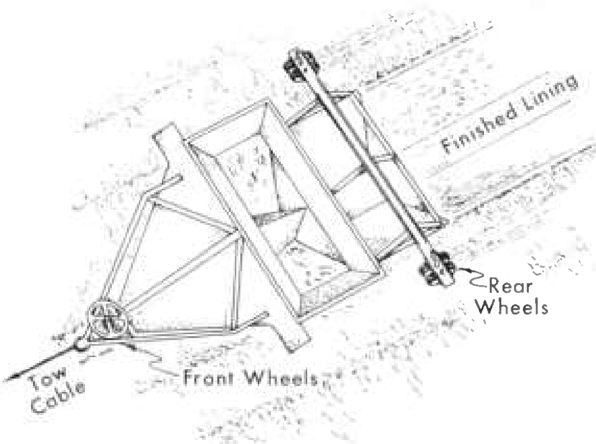

FIGURE 6.—Slip form shown in figure 5 with wheels added to convert it to a berm-guided slip form.

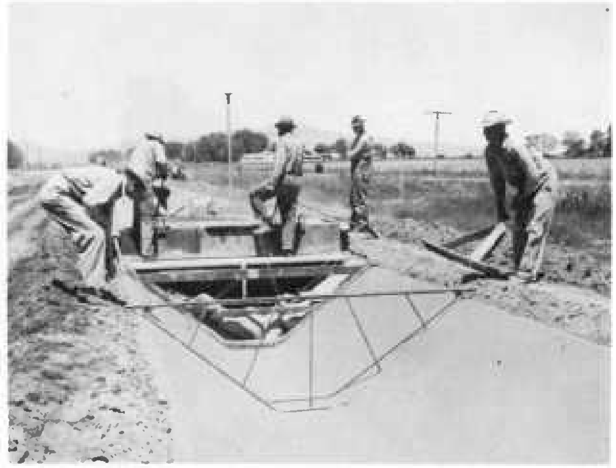

FIGURE 7.—Template used for making weakened plane joints.

will take place along the groove rather than at some other place. After the lining is grooved, the joints are calked.

The calking compound should be one that adheres to the concrete surfaces and maintains contact during cycles of contraction and expansion. The compound should be prepared according to specifications outlined by the U.S. Bureau of Reclamation.[2]

Panel-Formed Linings

Under some conditions and for small jobs, it may be cheaper to use the panel method of constructing ditches than to use a slip form. Panel-formed linings permit the lining of short sections of channels at times when labor is not needed for more expensive farm operations (fig. 8). This form of construction also offers advantages to farmers who wish to dig and line their own ditches.

After the ditch has been excavated, grade stakes are set along the center line at intervals corresponding to the length of the panel to be used. The stakes are set at elevations corresponding to the top of the finished lining.

The forms, or guide templates, usually consist of 2 x 4's on edge. The side 2 x 4 pieces are attached to the bottom 2 x 4 by bolts (fig. 9). The bottom member of the form is leveled with the top of the grade stake and the cross spacer bolted in place temporarily. The cross spacer is then centered over the bottom piece by means of a level or

[2] U.S. Bureau of Reclamation "Specifications for Sealing Compound, Rubberized, Cold Application, Ready-Mixed, for Joints in Concrete Canal Lining." February 25, 1960. 3 pp. [Processed.]

FIGURE 8.—Concrete lining being constructed by the panel method: Panel in foreground has just been screeded, a 10-foot space is skipped, and another panel is in the process of being placed.

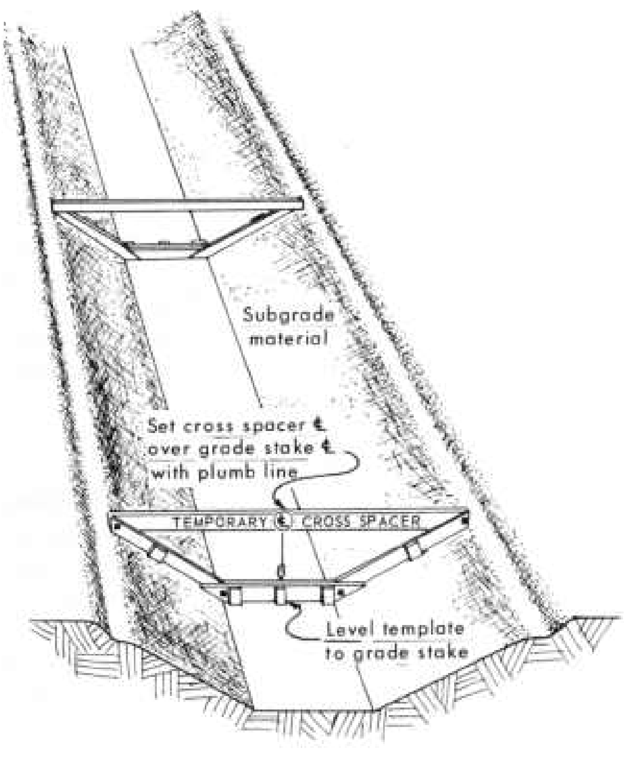

FIGURE 9.—Detail of guide templates for panel-formed concrete linings.

plumb bob so that both sides will have the same slope. The form is then fastened in place by driving stakes into the subgrade along both sides and nailing the form to them.

The second form is installed in the same manner at the next grade stake, 10 feet from the first form if panels are to be 10 feet long. A 2 x 4, the end spacer, is then staked parallel to the ditch along the top between the two cross members (fig. 10). The end spacer provides the top of the form. The temporary cross spacers are then removed from the cross members and the forms are in place.

As an aid to fine grading, a 2 x 6, slightly longer than the panel, is notched to a depth equal to the thickness of the concrete lining and fitted over the end forms. This piece is used as a guide in trimming the subgrade to the specified depth.

For a panel-formed lining, a relatively stiff concrete mix—a mix with a slump of 2 to 3 inches—is required. The freshly mixed concrete is placed in the formed area, either from a "ready mix" truck or from a mixer located adjacent to the job, and the concrete is spread over the formed area with a shovel.

The bottom is poured first, and then the fresh concrete screeded up the slope. If a rope is placed in the screed board, a worker standing at the top of the slope can pull the screed up the slope and assist those screeding the concrete by taking some of the load. As the screed board is sawed back and forth across the forms, concrete is added with a shovel ahead of the board to fill minor depressions and to keep a little excess material ahead of the board.

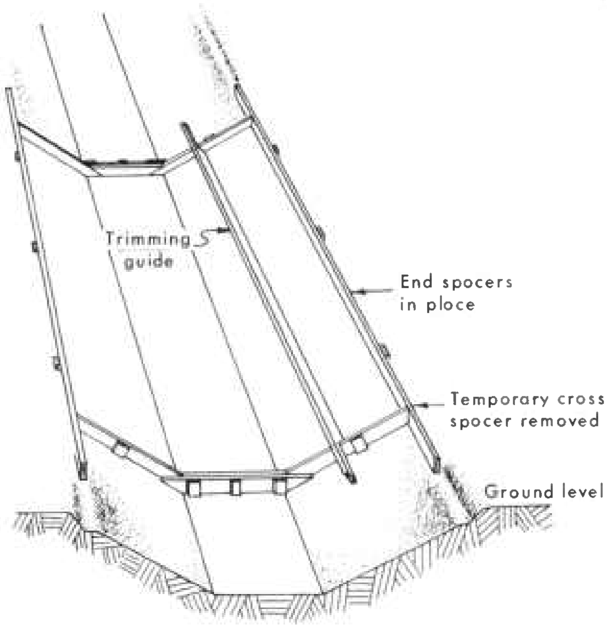

FIGURE 10.—Panel form in place and ready for concrete to be poured.

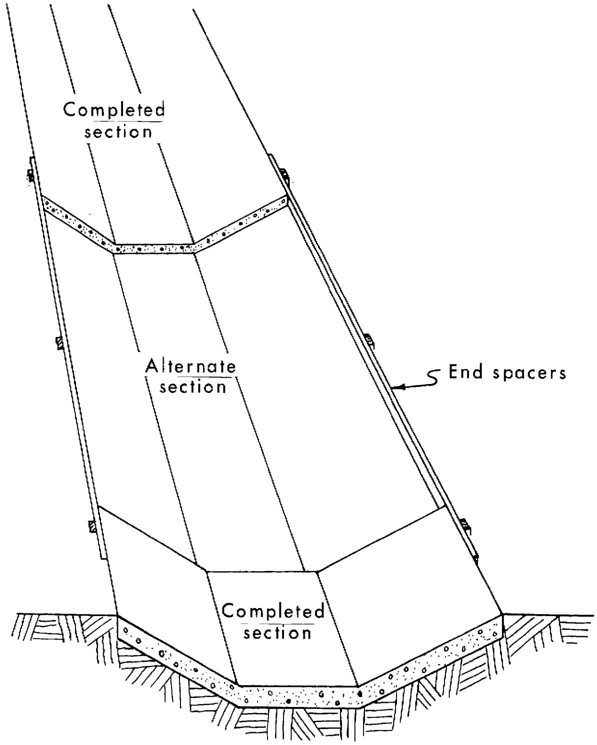

FIGURE 11.—End spacers in place on alternate sections of panel-formed lining.

If screeding is done properly, little finishing is required. A wooden float can be used to fill in small depressions, such as are caused by stones pulled under the screed, and to touch up the lining, if needed. After the concrete has taken an initial set, a barn broom can provide a final, acceptable finish with little work. The broom is dipped in water, shaken free of most of the water, and then pulled up the slope with light pressure. Curing is then carried out.

After the 10-foot space between the end form is lined with concrete, a 10-foot length of ditch is skipped and another set of forms put in. The skipped places are poured later. In constructing the connecting panels, the finished panels are used as end forms (fig. 11). The end spacer is staked against the top of the finished lining and alined with the top of the finished panels to complete the forming.

Formed Linings

Irrigation laterals along hillsides often have side slopes of 1:1, or steeper. For these sites, forms of lumber must be used to support the fresh concrete while it is setting (fig. 12). It is best if the forms are constructed in sections, so that they can be moved intact and reused as the job progresses.

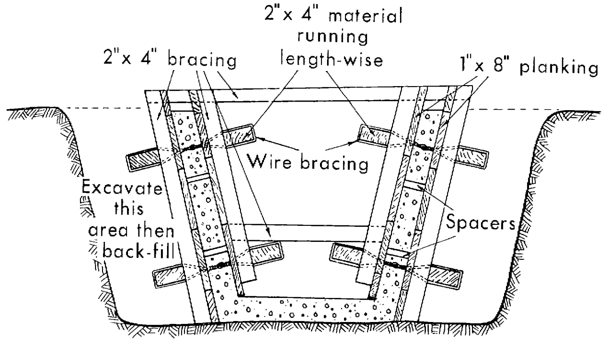

FIGURE 12.—Forms for concrete for vertical or near vertical irrigation laterals.

If the sides are vertical or nearly vertical, some reinforcing steel is used. Usually ⅜-inch bars on 1-foot centers both ways will give the necessary support.

ASPHALT LININGS

Asphalt is a petroleum product and is produced in a variety of types and grades, ranging from hard brittle solids to thin liquids. The semisolid form known as asphalt cement is used in lining channels. Asphalt cement consists of hard asphalt with non-volatile petroleum oils.

Buried asphalt membranes are used extensively for large canals. However, these buried linings are not adapted to small laterals or field ditches, particularly if they are used for irrigation only occasionally. Buried linings hold up the moisture and stimulate weed growth.

In areas where livestock are not allowed access to laterals and field ditches and where equipment does not have to cross these channels, exposed asphalt liners may be used. The life of these linings, although variable, will be shorter than that of concrete under most conditions. It is not possible to estimate the life with the information now available, but exposed asphalt liners will probably last less than 10 years. Asphalt liners have essentially the same hydraulic characteristics as concrete linings. Prefabricated asphalt liners tend to shrink and the joints to open.

Prefabricated Asphalt Liners

The plank-type prefabricated liners come in thicknesses of ¼ to ½ inch, fabricated in units 2 to 4 feet wide and 8 to 12 feet or more long. Although the thicker liners are relatively stiff, they will conform to the shape of the ditch if laid in warm weather.

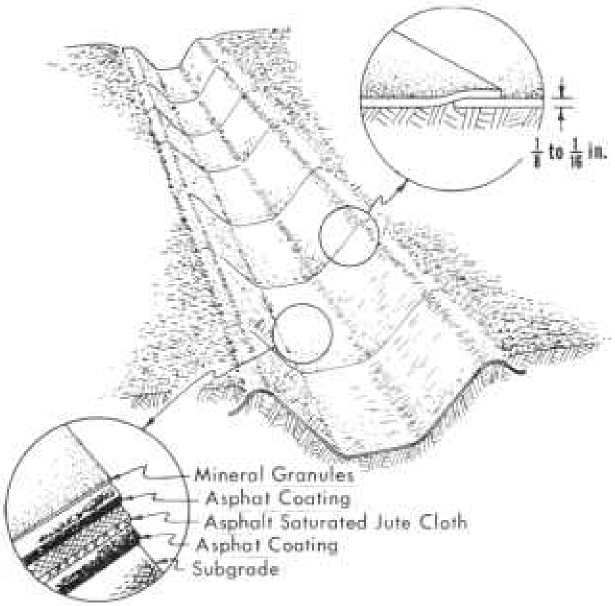

FIGURE 13.—Sheet of plank-type prefabricated asphaltic ditch liner in place.

Usually the sheets are installed transversely (fig. 13). If the sheets are lapped, the lap is downstream, so that the water will not put any stress on the joint. If the sheets are butted, a cap strip is used to cover the joint. If a ½-inch liner is used, the cap strip is usually ¼ inch thick and is 4 to 6 inches wide.

The lining should extend up the slope to a point above the designed water surface elevation to allow for the standard freeboard and to provide enough liner for burial in the berm as an anchor. Unless the lining is well anchored, it tends to sag on the slope and wrinkle.

Asphalt-Coated Jute Linings

The development of the asphalt-coated jute lining is in the experimental stage. This lining, like the plank-type linings, is susceptible to mechanical damage.

The liner is an asphalt-coated jute cloth (fig. 13). The processes that entered into the fabrication of the liner included:

1. Mildewproofing or rotproofing of a 15-ounce jute sacking by treatment with copper naphthanate;
2. Drying and saturating the sacking with asphalt, employing a high-penetration material to insure, insofar as possible, the coating of each jute fiber with asphalt;
3. Coating the asphalt-saturated fabric with a low-penetration asphalt;
4. Topcoating the fabric with weather-resistant granules;
5. Dusting, to prevent sticking, and packaging in rolls for handling and shipping.

The liner is approximately ⅛ inch thick. It is 40 inches wide and comes in rolls like roofing. A torch is used to weld it together. The topside and underside of the material at the joints are heated sufficiently to soften the asphalt, and the joints are then pressed together (fig. 14). The resulting seam is strong and, if carefully done, watertight. Installation is facilitated if several widths are welded together on the bank and later pulled into place, since it is easier to weld the pieces together on a flat surface (fig. 15).

FIGURE 14.—Seaming widths of liner together with a torch.

FIGURE 15.—A section of liner, composed of several widths seamed together on the bank, is pulled into place.

FIGURE 16.—Ditch prepared to receive lining. Note trench in berm for anchoring lining.

FIGURE 17.—Liner in place.

FIGURE 18.—Lined ditch in operation.

To hold the lining in place, the worker excavates a trench in the berm paralleling the ditch and buries the ends of the liner in the trench (fig. 16). After the liner is in place (fig. 17) the trench is backfilled with a blade and compacted with the wheel of a rubber-tired tractor or the track of a caterpillar tractor. The lined ditch is then ready to convey water (fig. 18).

Costs of Lining

Costs of lining channels vary widely. The following reports are cited as illustrations of costs on concrete linings at different locations and for different jobs. In Phoenix, Ariz., 1½-inch concrete slipform linings, 1 foot wide in the bottom and 18 inches deep, were constructed at 70 cents per linear foot, or $1.22 per square yard, in 1958. This cost included the preparation of the subgrade and installation of diversion structures, if the structures were supplied by the owner. At Delta, Utah, for the same size ditch, the cost was $1.25 per linear foot. The lining at Delta, however, was an inch thicker than that at Phoenix.

Unreinforced concrete linings, 3 inches thick, cost $2.50 to $3.00 per square yard. In areas where concrete aggregate is available locally, this cost includes preparation of the subgrade. The breakdown for such a ditch near Ogden, Utah, lined in 1950, where the 3-inch lining was constructed in 10-foot panels, was $0.88 for earthwork, $1.02 for concrete; and $0.72 for placing the concrete. The placement cost included the building of the forms and any hand grading required in addition to the placement and finishing of the concrete.

The ½-inch plank-type prefabricated asphalt liners are about $1.60 a square yard, f.o.b., at place of manufacture. Freight charges and installation costs must be added to this cost. The asphalt-coated jute liners will cost about $0.65 a square yard at the place of manufacture, somewhat less than the plank-type.

Although concrete linings cost more to construct, the annual cost of concrete linings may not be any greater than the cost of asphalt linings as the concrete will probably last longer than asphalt linings. If, however, good concrete aggregate is not available locally and foundation conditions are unstable, the asphalt liners will probably be more economical.

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