CONCRETE PIPE AND SLIP-FORMED DITCHES FOR IRRIGATION IN A NORTHERN REGION

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Downslope view to the southeast of the concrete, slip-formed ditch lining.

Concrete structures have been used to convey water for many years, but they have not been used extensively in irrigated fields where severe freezing and thawing occurs. The economic feasibility and practicality of concrete is being challenged by recent developments of lightweight products that have become available for distributing irrigation water.

To study the use of concrete products for conveying irrigation water, the Portland Cement Association, North Dakota Concrete Products Company, Bismarck, and the Concrete Sectional Culvert Company, Fargo, became interested in placing some facilities at the Carrington Irrigation Branch Station and provided a grant to initiate this work in 1964. Prior to this time the ditches were all unlined earth. Concrete was used to line a distribution ditch 730 feet long and provide a buried pipeline 1,836 feet long. These installations have been used and observed for nearly seven years.

The soil in the experimental area consisted mainly of Eckman loam. This soil is a well drained chernozem, weakly to moderately developed in loamy glacial meltwater deposits that may become sandy or have a friable till substratum below three to four feet (4).

The concrete pipeline was installed in a 24-inch wide trench which was excavated with a backhoe machine.

The first 1,400 feet of trench was prepared with a 0.3-foot sand bed and the remaining 436 feet was excavated to grade for the pipe. A grade of 0.25 percent was used. A minimum cover of 18 inches of earth fill was placed over the pipe so that the depth to the bottom of the pipe ranged from three to five feet. The pipe consisted of six-foot lengths of non-reinforced, 12-inch diameter concrete pipe with bell and spigot ends and rubber-gasketed (O-ring) joints. Manufactured tees were used to provide for six-inch risers which were spaced 72 feet on the line. Careful planning should be exercised in selecting the proper size and spacing of riser pipe. Eight-inch risers, for example, will allow nearly twice the discharge as six-inch risers at each outlet.

In 1964, the cost of the concrete pipe with risers and alfalfa valves plus trenching and bedding was about $2.00 per linear foot. Four men with a tractor laid the pipe at the rate of 100 feet per hour. Installing the risers and backfilling required two men and a tractor working at the rate of 230 feet per hour. Additional labor and materials are required for such accessories as drains, inlets and vents.

Lining was installed in the ditch using a slip-form machine designed for forming farm irrigation ditches. This method is illustrated by Laliberte, Rapp and Paziuk in Canadian Agricultural Engineering (2). An earth pad about one foot higher than the field was built and a ditch was shaped to conform to the slip-form machine. This produced a ditch three feet wide at the top with 1:1 sides and approximately 12 inches deep. The grade was 0.075 percent. Ready-mix concrete with a 2¾-inch slump was delivered to the site. The proper consistency of the concrete mix is very important for the machine to operate properly. As the slip-form was towed forward, a non-reinforced concrete lining approximately two inches thick flowed out behind the machine. Two test cylinders of the concrete were made, which failed at loads of 6,080

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and 4,970 pounds per square inch after a 90-day curing period.

Construction joints were formed by pushing a ⅜-inch thick plywood template into the freshly placed concrete. Joints spaced 6, 8 and 10 feet were randomly placed along the length of the ditch. Finally, the entire lining was sprayed with a liquid curing compound.

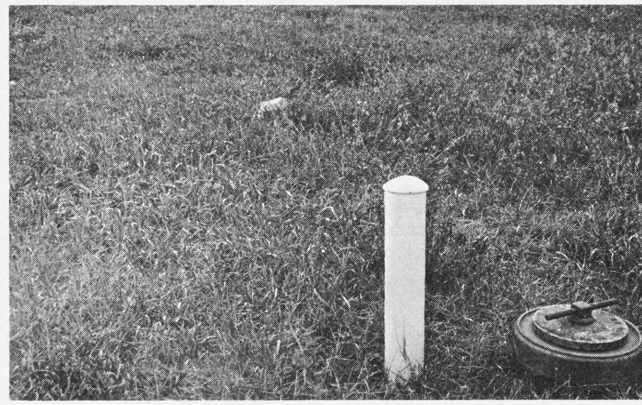
About 0.4 cu. yd. of earth fill and 0.033 cu. yd. of concrete were required for each linear foot of ditch. The balance of the installation cost was equipment rental, labor and supervision. Four men with a slip-form and winch could install about 180 feet of lining per hour.

Generally, buried pipeline is a more desirable means of conveying water than a concrete-lined ditch because it provides less interference with farming operations and makes water control easier. Although the cost of the concrete pipeline (Table 1) was somewhat higher than the lined ditch, some of the justifications for using buried pipe for water distribution are convenience in handling and mechanizing the system, reducing evaporation loss, less interference with farming operations, and a neat appearance at the head of the field. About half of the operation and maintenance cost on the concrete distribution ditch ($0.063/foot) was due to hand-furrowing the headland between the ditch and crop rows to allow distribution of water to the rows. This was not a problem with the unlined ditch because the furrows were established before the ditch was opened each year. The earth ditch was the most economical system of distributing water, but also the one with the most disadvantages. A minor problem existed with the pipeline risers. In some instances they blew off due to water pressure or were damaged by machinery and vehicles. Three-inch used boiler flue-pipe markers were later set at each hydrant to identify its location. This greatly reduced riser damage from farm equipment.

Table 1. Installation and Annual Costs Per Linear Foot of Water Handling Systems in 1964 at the Carrington Irrigation Branch Station (3).

	Distribution ditch			Conveyance ditch	
Cost items	Concrete pipeline	Concrete	Unlined earth	Concrete	Unlined earth
Installation	$2.25[a]	$0.780	$0.445	$0.780	$0.445
Annual Initial Cost	0.15[b]	0.063[c]	0.036[c]	0.063[c]	0.036[c]
Operation and Maintenance	0.02	0.063	0.053	0.030	0.057
Irrig. Labor	0.01	0.010	0.022	—	—
Total Annual Cost	$0.18	$0.136	$0.111	$0.093	$0.093

a Includes alfalfa valve outlets
b CRF at 5 percent for 30 yr. life
c CRF at 5 percent for 20 yr. life



A painted guardpost at an alfalfa valve outlet for the buried pipeline.

When the concrete lined ditch was treated as a conveyance ditch, its annual cost was about equal to the annual cost of an unlined earth ditch (Table 1). Weed mowing cost of $0.021 per linear foot was allowed along both the concrete and the unlined earth conveyance ditches. The balance of the operation and maintenance costs included $0.009 for silt removal in the concrete lined ditch and $0.036 for cleaning the unlined earth ditch (3). Since the annual costs of the conveyance systems are approximately equal, lining the earth ditch with concrete presents a more favorable means of conveying water because seepage loss is nearly eliminated. Also, the capacity of a smoother concrete lined ditch is greater than an earth ditch that has become overgrown with weeds or grass.

Elevations were taken annually on the hydrants of the pipeline. The deviation from the average elevation is shown in Figure 1 for the sand-bedded pipe and the pipe without bedding. Most of the apparent movement occurred within two years after construction. A certain amount of error existed in obtaining elevations, and any change in elevation of 0.02 foot or less is probably not significant. On this basis, the pipeline has remained relatively stable during the past five years. There seems to be somewhat more fluctuation where no sand bedding was used with this soil. However, the amount of movement is not great.

Annual elevations on bench marks placed in the invert of the concrete-lined ditch changed very little after the first year of construction (Figure 2). A change of 0.09 foot between November, 1964, and April, 1965, indicated some rather severe frost action during the first winter after construction.

In 1967, lateral cracking (cracks perpendicular to centerline of ditch) became evident in about one-third of the 10-foot sections and about 10 percent of the eight-foot sections of the ditch lining. Since that time, the amount of lateral cracking has not changed much and the lateral cracks have remained closed so that even by 1971 they appeared to be nearly invisible. Lateral cracking is probably due to inadequate depth of cut on the contraction joints. Contraction joints should be cut to a minimum depth of 25 percent of the thickness of the lining.

In 1968, a longitudinal crack (crack parallel to centerline of ditch) appeared in a six-foot and in an eight foot section. By 1971, about 10 percent of the sections had longitudinal cracks. These cracks usually occurred at the base of the sloping sidewalls on either or both sides of the lining. Although more cracks appeared in the 10-foot sections than the six-foot sections, longitudinal cracking should be a function of the condition of the subgrade when the ditch lining was placed. The longitudinal cracks opened so that dirt accumulated and weeds grew in them. These cracks could allow some rather severe seepage loss. Similar cracking believed to be caused by a high water table, has been noted in a slip-formed ditch near Hays, Alberta, Canada (2).

One of the longitudinal cracks that developed along the slip-formed concrete ditch lining.

Seepage loss from the concrete lining was not measured. The seepage loss rate at the Carrington

Fig. 1. Deviation from Average Elevations for Concrete Pipeline Installed in Fall, 1964.

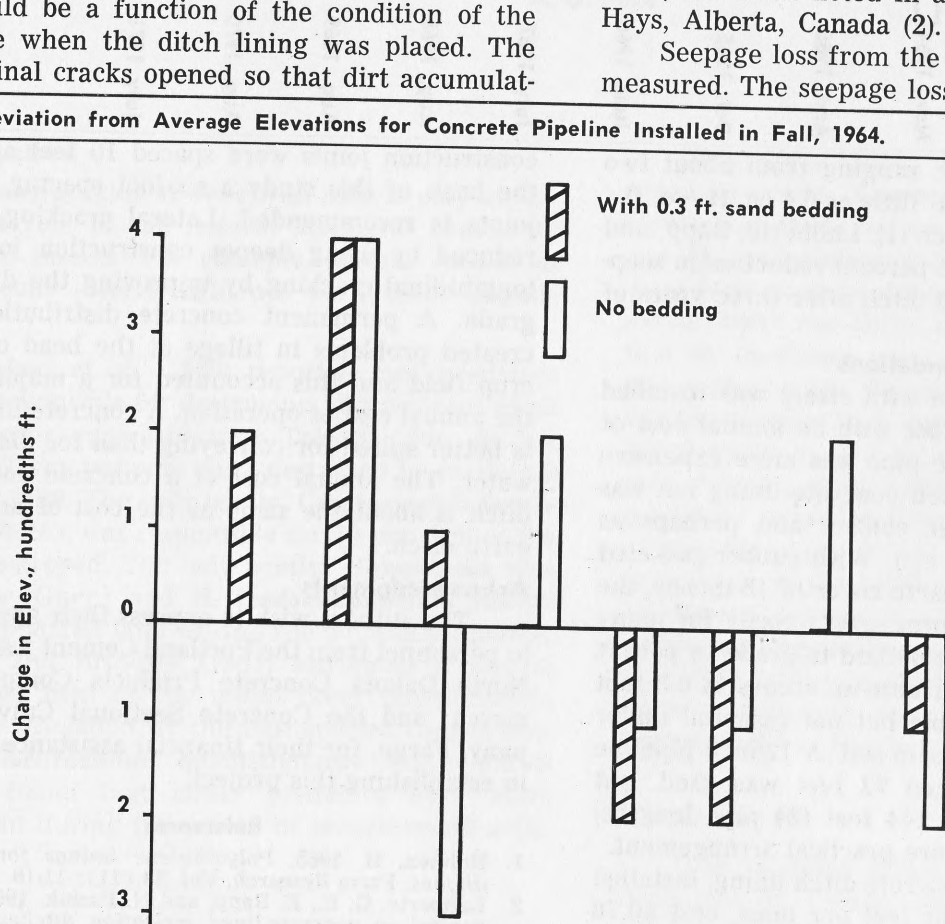
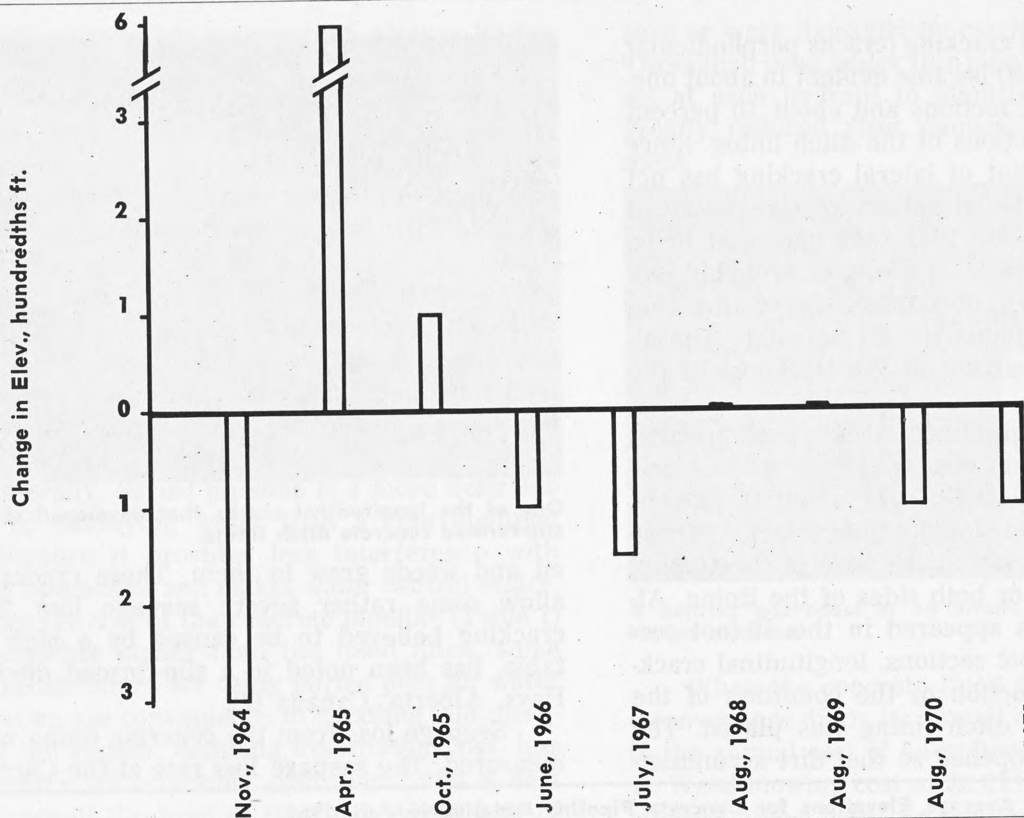


Fig. 2. Deviations from Average Elevations for Concrete Ditch Lining Installed in Fall, 1964.



station is relatively low, ranging from about two cu. ft./sq. ft./24 hrs. to as little as 0.4 cu. ft./sq. ft./ 24 hrs. in an unlined ditch (1). Laliberte, Rapp, and Paziuk (2) measured a 70 percent reduction in seepage loss in a slip-formed ditch after three years of service.

Summary and Recommendations

A concrete pipeline with risers was installed at a cost of $2.25 per foot with an annual cost of $0.18 per foot. Concrete pipe was more expensive to install than slip-formed concrete lining but was more effective in water control and perhaps as economical in the long run. With rubber-gasketed joints and a minimum earth cover of 18 inches, the concrete pipe will perform satisfactorily for many years. However, it must be laid to grade to permit draining before winter freeze-up occurs. A 0.3 foot sand bedding is desirable but not essential under the concrete pipe in a loam soil. A 12-inch pipeline with 6-inch risers spaced 72 feet was used, but 8-inch risers spaced at 144 feet (24 pipe lengths) intervals would be a more practical arrangement.

The slip-formed concrete ditch lining, installed at the rate of 180 linear feet per hour, cost $0.78 per foot. It had an annual cost of $0.136 per foot, when used as a distribution ditch and $0.093 per foot as a conveyance ditch. Non-reinforced lining, placed with a slip-form machine, appears to be relatively stable in the Eckman loam soil at the Carrington Station. Lateral and longitudinal cracks appeared after three to five years, especially where construction joints were spaced 10 feet apart. On the basis of this study a six-foot spacing between joints is recommended. Lateral cracking may be reduced by using deeper construction joints and longitudinal cracking by improving the ditch subgrade. A permanent concrete distribution ditch created problems in tillage at the head of a row-crop field and this accounted for a major part of the annual cost of operation. A concrete lined ditch is better suited for conveying than for distributing water. The annual cost of a concrete conveyance ditch is about the same as the cost of an unlined earth ditch.

Acknowledgments

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