NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD
SOUTH DAKOTA SUPPLEMENTS ITALICIZED

IRRIGATION WATER CONVEYANCE

NONREINFORCED CONCRETE DITCH AND CANAL LINING

(ft.)
CODE 428A

DEFINITION

A fixed lining of impervious material installed in an existing or newly constructed irrigation field ditch, irrigation canal, or lateral.

PURPOSE

This practice may be applied as part of a resource management system to support one or more of the following:

Improve control and management of irrigation water;
Prevent water logging of land due to excess seepage;
Maintain water quality;
Prevent erosion; and
Reduce water loss.

CONDITIONS WHERE PRACTICE APPLIES

This standard applies to concrete linings made of nonreinforced Portland cement concrete that is cast in place in a performed ditch or canal section but does not include linings of pneumatically applied mortar. *Nonreinforced concrete is typically "slip formed."*

This standard is restricted to installations in ditches or canals that have a bottom width not greater than 6 ft, a design capacity not greater than 100 ft^3/s, and a maximum velocity of 15 ft/s.

This standard includes design and construction criteria for shaping or reshaping the ditch section as well as for the lining.

Ditches and canals to be lined shall serve as integral parts of an irrigation water distribution or conveyance system that has been designed to facilitate the conservation use of soil and water resources on a farm or group of farms.

Water supplies and irrigation deliveries for the area served shall be sufficient to make irrigation practical for the crops to be grown and the irrigation water application methods to be used.

Lined ditches and canals shall be located where they are not susceptible to damage from side drainage flooding, or they shall be protected from such damage.

Nonreinforced concrete linings shall be installed only in well-drained soils or on sites where subgrade drainage facilities are installed with or before the lining. These linings shall not be installed on sites susceptible to severe frost heave or on sites where experience has indicated that the sulfate salt concentration in the soil causes rapid concrete deterioration. On sites where sulfate concentrations *is more than 0.1 percent*, concrete linings may be used only if they are made using special sulfate-resistant cement *as shown below.*

Types of Cement Required for Concrete Exposed to Sulfate Attack

Percentage water-soluble Sulfate (as SO_4) in soil samples	Sulfate (as SO_4) in water samples, ppm	Cement type
0.10 to 0.20	150 to 1,500	II, II w/Class F pozzolan[1] or IP (MS)[1]
0.20 to 2.0	1,500 to 10,000	V, V w/Class F pozzolan[2], II w/Class F pozzolan[2], or IP (MS)[2]
2.0 or more	10,000 or more	V plus Class F pozzolan[2]

[1]R factor less than 1.5 for substituted or blended cement.
[2]R factor less than 0.75 for substituted or blended cement, where R = (CaO-5)/ Fe_2O_3

CONSIDERATIONS

Water Quantity

Effects on the water budget, especially on volumes and rates of runoff, infiltration, evaporation, transpiration, and deep percolation and ground water recharge.

Effects on downstream flows or aquifers that would affect other water uses or users.

Potential use for Irrigation water management.

Potential changes in growth and transpiration of vegetation located next to the conveyance because of the elimination of leakage from the system.

Water Quality

Effects of installing the lining on the erosion of the earth conveyance and the movement of sediment and soluble and sediment-attached substances carried by water.

Effects on the movement of dissolved substances to ground water.

Effects on wetlands or water-related wildlife habitats.

Effects on the visual quality of water resources.

CRITERIA

Laws and Regulations. *This practice must conform to all federal, state, and local laws and regulations. Laws and regulations of particular concern include those involving water rights, land use, land disturbance by construction, pollution control, property easements, wetlands, preservation of cultural resources, and endangered species.*

General. *All irrigation systems shall be operated in accordance with an Irrigation Water Management (IWM) Plan. IWM plans shall be in accordance with the South Dakota Standard for Irrigation Water Management - Code 449.*

Capacity. A lined ditch or canal shall have enough capacity to meet its requirement as part of the planned irrigation water distribution or conveyance system without damage of overtopping. Design capacity shall be based on the following, whichever is greatest.

Capacity shall be enough to deliver the water needed for irrigation to meet the design peak consumptive use of the crops in the area served.

Capacity shall be enough to provide an adequate irrigation system for all methods of irrigation planned for use in the area served.

For design purposes, the capacity shall be considered to be equal to the capacity as computed with the Manning Formula by using a coefficient of roughness n of not less than 0.015.

Velocity. To avoid unstable surge flows, restrict a design velocity in excess of 1.7 times the critical velocity to straight reaches that discharge into a section or structure designed to reduce the velocity to less than critical velocity. The maximum velocity in these straight reaches shall be 15 ft/s. The velocity in ditch reaches from which water is to be delivered onto the field through turnouts, siphon tubes, or to similar means shall be less than super-critical and sufficiently low to permit operation of the planned takeout structure or device.

Freeboard. The required freeboard varies according to the size of the ditch or canal, the velocity of the water, the horizontal and vertical alignment, the amount of the storm or waste water that may be intercepted, and the change in the water surface elevation that may occur when any control structure is operating. The minimum freeboard for any lined ditch or canal shall be 3 in. of lining above the designed water surface.

This minimum freeboard requirement is based on the assumption that the finished channel bottom elevation will vary no more than 0.1 ft from the design elevation. If a construction deviation greater than 0.1 ft is permitted, the minimum freeboard shall be increased.

More freeboard shall be provided if required by slope velocity, depth of flow, alignment, obstruction, curves, and other site conditions.

Water surface elevations. All lined ditches and canals shall be designed so that the water surface elevations at field takeout points are high enough to provide the required flow onto the field surface. If ditch checks or other control structures are to be used to provide the necessary head, the backwater effect must be considered in computing freeboard requirements.

The required elevation of the water surface varies with the type of takeout structure or device used and the amount of water to be delivered through each. A minimum head of four inches shall be provided *(six inches is recommended).*

Where head is more than six inches on erosive soils, energy reduction devices may be needed on gates, turnouts, and siphon tubes.

Lining thickness. The thickness of canal linings must be established on the basis of engineering consideration on each job. Location, canal size, velocity, subgrade conditions, method of construction, operation, and climate shall be evaluated in establishing the thickness to be used. The minimum thickness for nonreinforced concrete linings in rectangular sections shall be 3 ½ in. For trapezoidal or parabolic sections, the minimum thickness shall be as shown in Table 2.

Table 2. Minimum Required Thickness for Nonreinforced Concrete Ditch and Canal Linings

Design velocity[1]	Minimum thickness by climatic area[2]	
	Warm	Cold
ft/s	*in*	*In*
Less than 9.0	1.5	2.0
9.0 - 12.0	2.0	2.5
12.0-15.0	2.5	3.0

[1]Velocities in short chute sections shall not be considered design velocity.

[2]Climatic area:

Warm - Average January temperature is 40 °F and above

Cold - Average January temperature is less than 40 °F.

Ditch or canal side slopes. Nonreinforced concrete linings generally are used in ditches and canals that have either trapezoidal or parabolic cross section.

They may be used in rectangular sections if the sidewall height is not greater than 1 ½ ft. Side slopes for usual construction methods shall not be steeper than shown below:

Hand-placed, formed concrete:
Height of lining less than 1½ ft……..Vertical

Hand-placed, screened concrete:
Height of lining less than 2½ ft….....3/4:1
Height of lining more than 2½ ft...…….....1:1

Slip form concrete:
Height of lining less than 3 ft.....…...1:1
Height of lining more than 3 ft.....……1¼:1

Ditch or canal banks. Ditch and canal banks shall be built up with earth to at least the top edge of the lining. In cut sections, other than in rock, a berm shall be constructed not less than two inches above the top of the lining. Banks and berms shall be wide enough to insure stability of fills and to prevent excessive deposition in cut sections.

Where siphon tubes are to be used, berm or bank top widths must be at least 12 inches wide. Other berm or bank top widths must be at least 18 inches wide.

If the bank or berm is to be used as a roadway, the minimum top width shall be adequate for the purpose, *but not less than 10 feet.*

Outside bank slopes and slopes above the berm elevation in cut sections must be flat enough to insure stability, *and allow maintenance*.

Related structures. Plans for installing ditch or canal linings shall provide for adequate inlets, outlets, turnouts, checks, crossings, and other related structures needed for successful conservation irrigation. These structures can be installed before, during, or after placement of the lining. They must be constructed or installed in such a way as not to damage the lining or to impair its effectiveness.

Materials. All materials shall meet or exceed the minimum requirements indicated under specifications for "Materials."

PLANS AND SPECIFICATIONS

Plans and specifications for installing nonreinforced concrete irrigation ditch and canal linings shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

OPERATION AND MAINTENANCE

An Operation and Maintenance Plan must be prepared for use by the landowner or operator responsible for operation and maintenance. The plan should provide specific instructions to insure the practice functions properly. Minimum requirements to be addressed in the Operation and Maintenance Plan are:

Prompt repair or replacement of damaged components as necessary;

Remove debris and foreign material; and

Maintain good vegetative cover on all slopes and watercourses.

REFERENCES

USDA-NRCS, National Engineering Field Handbook for Conservation Practices, Chapters 3, 6 and 15.

ASAE Standard S289.1, Concrete Slip-form Canal Linings.

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GENERAL SPECIFICATIONS

INSTALLATION

Foundation preparation. The foundation area for all ditch embankments and/or ditch pads shall be cleared of all trees, weeds, sod, loose rock or other materials not suitable for the subgrade. All trees with root systems that are a hazard to the ditch or canal lining shall be removed.

Placement of earthfill. The moisture content and methods of placing and compacting the material shall insure that a firm, stable embankment results. The fill material shall be placed in horizontal lifts of such thickness that proper compaction and prescribed densities are obtained.

Embankment materials shall be free of brush, roots, sod, large rocks, frozen soil, or other material not suitable for making compacted fills.

Excavation. Ditches and canals shall be excavated to the neat lines of the specified cross section and finished with a smooth, firm surface. Overexcavated areas shall be backfilled with moist soil compacted to the density of the surrounding material. No abrupt deviations from design grade or horizontal alignments shall be permitted.

Concrete placement and curing. All surfaces on which concrete linings are to be placed shall be moist when the concrete is poured. Slip forms and screeding equipment shall be operated so as to place the concrete uniformly across the perimeter of the ditch or canal, with a minimum thickness not less than that specified. Concrete shall not be placed on mud, excessively dry soil, uncompacted fill, ice or frozen subgrade.

Concrete linings shall be constructed to at least the thickness shown on the plans or as specified for the job or both. Finished lining grades shall not vary above or below the design channel grade by more than the deviation assumed in computing the freeboard requirements and as specified for the job.

Concrete linings shall have a smooth and uniform finish and shall be free of honeycomb.

Concrete shall be cured for not less than 5 days by (1) impounding water over the exposed surface, (2) covering with burlap or a similar material that is kept continuously moist, or (3) spraying a concrete sealing compound evenly over all exposed surfaces according to the manufacturer's directions.

Contraction and construction joints. Contraction joints, at least ¼ in. wide, shall be cut transversely in the concrete to a depth of about one-third the thickness of the lining at a uniform spacing not greater then 10 ft. Construction joints shall be the butt type formed square with the lining surface and at right angles to the ditch or canal. Contraction and construction joints shall be tooled so that the edges will have a smooth finish.

Construction operations. Construction operations shall be done in such a manner that erosion and air and water pollution are minimized and held within legal limits. The completed job shall be workmanlike and shall present a good appearance.

If conditions warrant, concrete shall be protected from freezing for at least 3 days after placement.

The use of accelerators or antifreeze compounds shall not be allowed.

Concrete damaged by freezing shall be considered defective work and must be removed and replaced according to these specifications.

MATERIALS

Concrete. Concrete used in ditch and canal linings shall be proportioned so that it is plastic enough for thorough consolidation and stiff enough to stay in place on the side slopes. A dense, durable product shall be required. The concrete mix shall be one that can be certified as suitable to produce a 28-day compressive strength of 2,000 lb/in.^{2} or greater.

Ready mix may be used if the concrete is mixed and delivered according to ASTM Designation C-94, and the cement content and maximum size aggregate conform to the requirements shown in the preceding paragraphs. Ready-mix concrete shall be discharged from the truck mixer within 1 ½ hours after water is mixed with the cement and aggregates, or the cement with the aggregates. If the air temperature exceeds 90 degrees F, the discharge time shall be reduced to 45 minutes.

Cement. The cement used shall be Portland cement, Types I, IP (MS), II, or V as specified for the job. Approved Class F pozzolans with LDI factor less than 3 percent may be used to replace not more than 15 percent of the cement by absolute volume. The R factor for class F pozzolan will be determined by the formula $R=(CaO-5)/Fe_2O_3$. This requirement applies to fly ashes used in blended or interground cement or fly ash used as a substitute for cement at the time of batching. Refer to the table on page 1 of this standard for R factor values. The cement content shall not be less than 4.5 bags/yd^3 of concrete.

Water. Water used in mixing shall be clean and free from harmful amounts of sediments, salts, or organic impurities.

Aggregates. Aggregates shall conform to ASTM Designation C-33, Standard Specification for Concrete Aggregates, except that pit-run aggregates may be used if they are well graded, clean, and durable. Maximum size shall not exceed one-half the specified lining thickness.