Concrete Lined Irrigation Channels
Causes of Failure

1 Overview

The purpose of this section is to give an appreciation of the factors that may contribute to deterioration in concrete channel linings and how they may interact. This knowledge is essential to the correct diagnosis of problems prior to formulation of appropriate solutions.

Concrete channel linings are typically 50 to 75 mm in thickness and are rarely reinforced. These linings are, therefore, just that – thin linings with little or no structural capability of their own.

The useful life of such a lining will, in fact, depend very much on the outside influences that bear upon it. Although concrete is tough, resists abrasion and is relatively impermeable, it is not capable, in thin unreinforced sections, of resisting many of the stresses linings are subjected to. The result is distress in the material, typically cracking, and subsequent deterioration.

The useful life of a concrete channel lining, then, will depend on such factors as the stability of its foundation material, the physical details of the channel and a variety of accidental external influences, from tree roots to tractor wheels. Useful life may also be influenced by the concrete materials themselves, abrasion from water and silt carried, and the chemical attributes of the water, both inside and outside the lining.

It is thus impossible to give meaningful global definitions of "failure" and "end of useful life", as they are highly case-specific. One concrete channel, formed in rock, might perform usefully for seventy years in spite of the presence of considerable cracking, while another channel might collapse in five years through leakage from one crack or joint washing away the foundation soil beneath it.

Before deciding on repair or replacement options, two factors must be considered:

- The real cause(s) of the problem(s) must be identified and either neutralised or taken into account, and
- The relative economic ramifications of a continuing repair programme or total replacement must be assessed for individual cases.

If the first factor is ignored, then it is likely that the repairs (or replacement) will fail in the same manner as did the original lining. Repeated cycles of repair/failure/repair are well known to many irrigation authorities already.

The second, economic, factor is difficult to assess and is also somewhat specific to the location involved. Measures which prove economic in one area may well be much less attractive in another. General guidelines can be helpful, but should be viewed with some suspicion and checked carefully in the context of the specific location and problem involved.

Two phenomena which can lead to deterioration and eventual failure of a concrete channel lining are cracking and chemical attack. It should be noted, however, that these rarely cause problems in isolation, but are usually the precursors or triggers for some other mechanism of deterioration.

2 Cracking

Although concrete is hard and tough, it is a brittle material and has relatively little capacity for resisting tensile stresses. When it is subject to more than a small amount of tension, concrete cracks.

When a concrete section contains steel reinforcement, the steel takes up the strain and resists tension once cracking has occurred. In this scenario, cracks tend to be limited in width, since the elongation of the steel across the cracks is minimal. Note that the steel does not prevent cracking, it merely controls crack width, while also preventing displacement of the concrete at either side of a crack.

In unreinforced sections, cracks can grow wider and relative displacement of the concrete pieces at either side of a crack can occur. The inclusion of steel fibres in the concrete can replace the action of conventional steel reinforcement to some extent, by boosting the tensile capacity of the concrete. Plastic fibres, on the other hand, although having useful attributes, cannot control cracking in hardened concrete unless present in doses so large that they are impracticable and uneconomic.

The causes of most cracking in concrete channel linings are as follows:

2.1 Shrinkage

A small slab of concrete, left to dry out after casting, will shrink as it loses moisture. Some of this shrinkage is irreversible, and some occurs even in concrete that is kept wet for much of its life.

Such shrinkage means that a slab of concrete will try to become smaller. If this tendency to shrink is resisted in any way, the result will be tension in the concrete, and sufficient tension will cause cracking.

Unless frequent joints are provided, the weight of the concrete itself, together with friction against the ground, will restrain shrinkage movement. Joints that consist of deep grooves, scores or cuts in the concrete are really “planned cracks”, in that the grooves are deliberate weak points at which all cracking is encouraged to occur.

Caulked construction joints and/or grooved contraction joints are generally provided in concrete channel linings, but they are rarely provided frequently enough to ensure that the lining is crack-free. Recommendations from the US Bureau of Reclamation for joint spacings in unreinforced concrete are as follows:

Lining thickness	Joint spacing
50 to 65 mm	3.0 m
75 to 100 mm	3.5 to 4.5 m

The adoption of such spacings should minimise shrinkage cracking in the lining, remembering also that longitudinal joints may be required in larger channels or canals. Joints and their repair are dealt with in another section.

2.2 Thermal Movement

In this context, thermal movement occurs in three distinct phases. The first is thermal shrinkage as a freshly placed concrete lining cools in its first hours of life. This can cause early shrinkage cracking in much the same way as drying shrinkage.

Further thermal movement can occur in concrete exposed to the elements, when it heats and cools with daily temperature fluctuations. This is particularly relevant for the exposed tops of channel linings, and results in constant opening and closing of fine cracks.

A further source of distress and cracking in channel linings is thermal shock, when cool water is flooded into a channel which has been empty and exposed to the sun. This causes sudden large-scale contraction and can initiate cracking or open existing cracks.

2.3 External Pressures

Concrete channel linings can become distressed and cracked by tension caused by a variety of external sources of pressure. Common ones include:

- Vehicles and equipment operating near the top of the channel
- High external water levels, particularly if the channel is empty
- Rapid draw-down of the channel level causing the above
- Growth of tree roots pressing on the channel lining
- Structural distortion caused by loss of soil support
- Gross movement or settlement of the supporting soils
- Swelling and shrinking of the supporting soils

2.4 Consequences of Cracking

Whatever the source of cracking in concrete channel linings, cracks can permit seepage and loss of water from the channel. This may be only a minor irritant, may cause objectionable local flooding, or may cause loss of the supporting soil through erosion and piping, with subsequent major damage to the lining.

Thus a simple shrinkage crack, in some soils, can trigger further damage and total failure of the channel at an early date. It may also cause disruption of the channel through swelling of reactive clays.

If considerable cracking occurs immediately downstream of a control structure, then local turbulence can dislodge pieces of the channel lining and lead to large-scale disintegration and local undermining of the structure.

3 Chemical Attack

In the context of irrigation channels, chemical attack of concrete linings generally takes the form of attack by aggressive waters. Aggressive waters can be those carried by the channel itself, or they can exist in the soils which support it. In either case, deterioration of the concrete is usually slow.

Concrete is an alkaline material and is prone to attack by acids. In practice, dissolution is extremely slow until the pH drops below about 6.5, when some of its compounds dissolve more rapidly. These conditions can exist in some soils.

If sulphates of magnesium and sodium are present in the soil surrounding a channel, the groundwaters may cause sulphate attack with consequent deterioration of the concrete lining from the outside.

Another common cause of slow dissolution is attack by waters deficient in dissolved calcium bicarbonate. Pure water, such as rainwater in non-industrial areas, can meet this description if it does not pick up the relevant minerals from the ground over which it flows. It will then leach calcium minerals from the concrete to cause slow dissolution.

If such waters are carried by channels, their inside surfaces will suffer this degradation and it will be exacerbated by erosion effects such as scouring of the concrete surface by silts (or fine particles of the concrete itself) carried by the flow.

Conditions such as these will shorten the life of a concrete lining unless it is protected by some sort of coating or membrane.

4 References

Ryan, W.G. and Samarin, A., 'Australian Concrete Technology', Longman Cheshire.

Neville, A.M. and Brooks, J.J., 'Concrete Technology' Longman Scientific & Technical.

Kraatz, D.B., 'Irrigation Canal Lining', Food and Agriculture Organisation of the United Nations, Rome 1977.

United States Department of the Interior, Bureau of Reclamation, 'Linings for Irrigation Canals'.

Gowripalan, N., 'Basic Fibre Theory, Fibre Types and Current Trends', Seminar Paper, Fibres in Concrete 97.

MARLIN, "a computer-based procedure to help assess irrigation schemes and pinpoint areas where repairs would be most cost-effective" – contact Gez Cornish at HR Wallingford, UK, e-mail: gac@hrwallingford.co.uk

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