Concrete Irrigation Channels – Relining

1 Overview

The term ‘relining’ is used in this context to denote the process of applying a new impermeable lining over an existing, deteriorated, concrete lining. The old concrete lining then functions as a base support layer for the new inner lining, which will maintain the shape of the channel.

This approach will generally be cheaper than demolishing and re-building the existing channel, provided the old lining is substantially intact and holding its shape.

The choice then has to be made between a rigid inner lining and a flexible one, and between an inner lining which adheres to the existing concrete and one which merely rests on it.

A prime consideration in this choice, as in many other repair options, is the likelihood of future movement in the channel structure. A rigid lining will only work well if, like the original lining, it remains uncracked. Any movement in the supporting structure is likely to cause cracking in a new rigid lining.

Similarly, any applied (adhered) lining would have to be very flexible to bridge active cracks and maintain its integrity. Additionally, the success of such linings depends very much on good surface preparation for a good bond, a consideration which often makes such solutions expensive.

Although the foregoing comments make it seem as though a flexible, non-adhered inner lining is the only practical choice to make, life is not so simple. Such liners have shortcomings of their own, including a general lack of toughness and some vulnerability to a variety of influences likely to cause accidental damage. If they were installed and then further protected by a tough overcoating such as concrete, the total system would be very expensive.

The choice in any particular case must, therefore, be a compromise between desired attributes, cost and expediency. This is always a difficult type of problem, and is complicated in the case of channel linings by considerations of the required (or desired) residual life of the channel and hence the overall cost in dollars per metre per year.

2 Issues to be Considered

In order to achieve an acceptable result with a relining exercise, the new inner lining must be watertight, durable, hydraulically efficient and implemented at reasonable cost.

In order to remain watertight, the lining must maintain its integrity. It must not crack, split, tear, part company from the old lining, or deteriorate significantly within the service life required of it. Thus it must not only accommodate movement, from whatever cause, but must also be durable within the context of the time span chosen for it.

These requirements are not easy to meet, since some of the required properties are mutually exclusive. For instance, the more flexible a material is, the more susceptible it is likely to be to accidental damage, and the more likely it is to be dislodged by circumstances such as outside water pressure while the channel is empty.

Advances in materials technology are producing flexible plastics capable of resisting UV exposure for long periods, tough enough to resist tearing quite well (and repairable if it does occur) and still flexible enough to accommodate reasonable degrees of movement.

Unfortunately, increases in a property such as UV resistance are usually achieved at the expense of another property such as flexibility, so there are limits to what can realistically be produced. All such plastics also tend to expand and contract markedly in response to thermal changes and none is fireproof.

All of these drawbacks can be overcome if the plastic liner is itself protected – by a layer of clay soil or concrete, say. This would protect it from UV and fire, minimise temperature effects, protect it from most accidental damage and weigh it down against uplift pressures when the channel is empty.

The trade-off for such an approach is greatly increased installation cost, and a reduction in channel volume unless the sides are also raised to maintain water depth (a consideration which applies equally to any thick lining).

There are no easy answers or short cuts to deciding between such options. Each case must be looked at on its merits and within its own constraints. If the channel is vital enough and expected to last for long enough, perhaps the extra cost of the ‘full house’ approach might be justified. Otherwise, compromises must be accepted, perhaps a reduced service life or more intensive maintenance requirements in exchange for much lower cost and a reduced construction time.

A further consideration is that of channel maintenance work on the new lining. If periodic removal of silt is a requirement, then hard linings will permit the continued use of machinery such as skid-steer loaders, while some of the ‘softer’ options like plastic membranes might dictate the adoption of alternative technology such as suction dredging.

3 Options for Relining

The following sections describe various possible options for the application of a new inner lining to an existing concrete-lined channel, listed as generic types rather than as specific brand names. All have been tried, either in Australia or overseas, and comments are made on their pros and cons in use.

3.1 Cementitious Render

This approach consists of applying a thin sand/cement render to the inside of the channel, with or without the addition of a waterproofing agent.

Rendering could have merit if the main problem with the original channel is loss of concrete by erosion or chemical attack, but it is less likely to succeed if the original channel is subject to extensive cracking. One problem with a render or topping is that cracking tends to reflect through it eventually, even if the cracks are relatively stable. For the same reason, it is essential that every joint in the original lining is matched by a joint in the render.

It is also essential that the surface of the parent concrete be thoroughly cleaned and slightly roughened if a good bond is to be achieved with the render. Bonding agents can be applied to the concrete and/or mixed into the render and they are effective, but they increase expense without negating the need for thorough preparation.

3.2 Sprayed Polyurethane Foam

Sprayed polyurethane foam has been trialled for canal lining by the US Bureau of Reclamation, spraying it onto a channel in rock, which approximates a relining project. This material is very good for covering and waterproofing irregular surfaces.

The rather soft sprayed foam was protected by a surface layer of a harder grade of sprayed polyurethane coating.

In practice, this system proved to be less than durable, much of the foam being washed away within five years. Any foam which was not perfectly adhered to a solid foundation was easily dislodged, and the foam proved buoyant enough to make loose pieces of substrate float away if bonded to it.

3.3 Sprayed Membranes

The trials mentioned above also included the use of sprayed formed-in-place membranes of neoprene-polymer-modified asphalt over both steel and concrete substrates.

This material was very easy to apply, but failed quite quickly, becoming dislodged completely from the channel bottom in the first year. It would also have suffered if standard maintenance procedures had been used to remove silt from the channel.

It is, however, acknowledged that the performance of the membrane would probably have been greatly improved by better cleaning of the concrete, by using abrasive or water blast rather than by merely scrubbing.

3.4 Sprayed Concrete

(NB. Sprayed Concrete is covered in detail in a separate topic. Please refer to the Guidelines for "Shotcrete" for more information).

Sprayed concrete (gunite if using aggregates smaller than 10 mm and shotcrete if using larger ones) has a long history of use throughout the world. It economical and easy to apply, but is still a brittle material and prone to cracking – either through its own shrinkage, or reflecting movement in existing cracks.

The best defence against cracking is to detail the sprayed concrete like any other concrete, with joints at frequent intervals. If cracks in the existing lining are active, sprayed concrete is probably not the best choice for relining.

Attempts have been made to minimise the cracking problem by including fibres of various types in the sprayed concrete mix, but their effect in this regard is uncertain. Steel fibres can certainly boost the tensile strength of the concrete sufficiently to help with crack control (although not necessarily prevention), but the benefit of plastic fibres is probably limited to the reduction of rebound when spraying.

US Bureau of Reclamation trials showed no difference in performance between steel fibre reinforced, plastic fibre reinforced and unreinforced sprayed concrete after five years. They did, however, confirm that rusting of steel fibres was confined to the concrete surface, the fibres below the surface being totally unaffected.

Sprayed concrete would be a good choice for relining a fairly stable channel, given correct concrete preparation and good detailing of the new lining. It is certainly tough and durable and would permit the continued use of standard channel cleaning procedures.

3.5 Sheet Plastic Membranes

(NB. Flexible membranes are covered in detail in a separate topic. Please refer to the "Geomembranes" topic page within this document for more information).

This category covers relining a channel with one of a wide variety of sheet membranes, such as PVC, high density polyethylene (HDPE), low density polyethylene (LDPE), polypropylene, etc. The rival merits of the different materials and formulations are discussed in a separate section, only the general principles being covered here.

The principal advantage of sheet membrane linings is that they are totally watertight unless damaged. Unfortunately, their principal drawback is their susceptibility to various forms of damage.

The thinner the sheet material, the easier it is to puncture or tear, whether it is stretched over jagged edges, exposed to accidental abrasion, or attacked by vandals. It has been found in Australia that thicknesses of 1 – 2 mm perform best, but (of course) the thicker membranes cost more and are possibly more difficult to handle when installing.

All of the plastic membranes are, to some degree, also susceptible to UV degradation, environmental cracking through thermal movement and melting if exposed to bushfires. Given the right thickness and formulation, however, linings such as HDPE are performing well so far and promise to do so for over 20 years.

One problem which has been noted with most of the plastics is that of their slippery nature. When people or animals fall into a plastic-lined channel, they find it very difficult to climb back out. Animal-proof fencing seems an unlikely solution to this problem, but one Queensland Scheme has had success with the provision of rubber escape mats hanging over the channel sides at regular intervals.

3.6 Grout Injected Mattress

Another option which has been trialled both in Australia and in the USA, grout injected mattresses consist of two layers of a woven or punched geotextile fabric, connected together at regular intervals. When a cementitious grout is pumped into the space between the layers of fabric, the result is a concrete-filled ‘quilt’ of some 75 mm thickness.

The preferred choice for water retaining applications is a mattress with a uniform cross section rather than one with pressure relief holes through it. Both types have a long history of application in erosion control works.

When hardened, grout-filled mattresses have all the advantages of a concrete lining but are much easier to form in place. Being brittle, however, they are also susceptible to cracking should movement occur in the underlying structure.

Mattresses are available in different fabrics, each with its own attributes and each with its own price. Rival claims for the various materials are sometimes difficult to verify, but experience is beginning to indicate that nylon is more durable than polyester.

Whichever fabric is used, it may perish and/or abrade away in time. The abrasion performance of the grout filling once this occurs is currently unknown in the context of channel linings.

4 Installation Considerations

This section considers some of the key considerations for successful installation of each of the above lining types. They must be observed in full if the lining is to last, so they should be allowed for in costings and should never be skimped in the press of contract execution.

4.1 Cementitious Render

As with most adhered linings, cement renders, whether polymer-modified or not, depend very much on being applied to a clean, slightly roughened substrate if they are to bond properly in place.

This can be achieved by high-pressure water blasting, by grit blasting, or by a variety of mechanical methods. The mechanical methods (scabbling, needle-gunning, etc) are labour intensive and slow if done thoroughly, so they are unlikely to be economic for large areas.

Grit blasting can present a dust hazard unless a wet grit blast is employed, but then the effluent must be captured and controlled. Water blasting also produces an effluent problem, but on a smaller scale. Various options do exist for collecting, filtering and re-using the water from these operations, but they represent an extra cost to be accommodated.

4.2 Sprayed Polyurethane Foam

Preparation for the application of sprayed polyurethane foam, like preparation for rendering, must revolve around the production of a sound, clean, slightly keyed surface upon which to spray the product.

Since this approach is not recommended for use, no further comment is given. If local trials are to be conducted with this system, the manufacturer's advice should be sought concerning materials, methods and hazards.

4.3 Sprayed Membranes

As for sprayed polyurethane foam.

4.4 Sprayed Concrete

(NB. Sprayed Concrete is covered in detail in a separate topic. Please refer to the Guidelines for Shotcrete for more information).

Surfaces to be sprayed with concrete must first be cleaned of all loose and unsound material. The old lining should also be repaired by filling any holes and sealing any large cracks to eliminate abrupt changes in thickness of the sprayed layer.

When a fair, sound surface has been obtained, it should be roughened by scabbling, high-pressure water blasting or wet grit blasting. Just prior to spraying, the old concrete should be thoroughly cleaned and wetted, the sprayed concrete being applied just after the water sheen has disappeared.

Ideally, the nozzleman spraying the concrete should scour the surface of the old lining ahead of the application with an air/water jet.

Improper preparatory work is responsible for more sprayed-concrete failures in repair work than any other single factor.

A skilled operator with good equipment can then build up the required thickness of concrete by making a series of overlapping passes in a pattern to cover the working area. To minimise rebound, the nozzle should be held nearly perpendicular to the concrete surface, at a distance of 600 to 1200 mm.

It is customary to start work at the bottom of the channel, since it is easier to clean rebound off completed work than off a prepared surface. An even thickness of new concrete is desired, and this is assured by using profiles or tensioned wires as guides while spraying.

Once in place, sprayed concrete is just like any other concrete. It can be left with an 'as-sprayed' finish, or it can be trowelled for a smoother surface.

4.5 Sheet Plastic Membranes

(NB. Flexible membranes are covered in detail in a separate topic. Please refer to the "Geomembranes" topic page within this document for more information).

The old lining does not need such rigorous cleaning for the application of a sheet membrane, but it does need to be smoothed if the plastic membrane is to remain unpunctured.

All loose material should be removed, all voids or badly broken places filled and patched, and all cracks filled and smoothed over. Without this degree of preparation, the sheet plastic could be punctured by loose stones or jagged concrete, or could be torn as water pressure after channel filling pressed it into cracks or over sharp edges.

Whether the membrane is laid as a series of overlapping strips across the channel, or as strips along the channel, its edges must be adequately anchored at the tops of the channel sides. A cheap and effective method for achieving this is to form a ditch at each side of the channel, tuck the plastic sheet into the ditches, and backfill the ditches with soil.

The ends of the relined section have also to be anchored, in addition to places where the sheet membrane abuts control structures. This anchoring is best effected by stainless steel or aluminium strips laid on top of the membrane and fixed through into the concrete beneath.

Two other installation considerations concern sealing of the overlaps between strips of sheeting, and coping with thermal movement of the plastic during installation. Seam sealing can be done either with a hot metal wedge to melt the two layers together, or by pressing a strip of adhesive or melted plastic between them.

Coping with thermal movement is trickier, especially in a material such as HDPE, which has a high coefficient of thermal expansion. Since this means that the sheeting will expand during the heat of the day, it is important that all anchoring, smoothing and fixing be done while the liner is cool. If anchoring is done while the liner is hot, thermal contraction during the night following could tear the plastic away from its fixings.

4.6 Grout Injected Mattress

For best results with grout injected mattresses, preparation of the old lining should be similar to that for sheet plastic membranes, although not so rigorous. Sharp edges and abrupt changes in thickness should be avoided, as these will become stress points or thin patches later.

The mattresses can then be laid out to cover the channel profile, anchored temporarily with pegs and butt-joined with zips, welds, or sewn seams, depending on the system in use.

The mattresses must be anchored at the upstream and downstream ends of the relined section, and this is easily accomplished by forming trenches across the channel, tucking the mattresses into them and concreting them in when filled.

The edges of the mattress along the tops of the channel sides may not require anchoring once the grout has hardened, depending on channel size, flow velocity, etc. Sometimes, the mattress is merely terminated at the top of the channel sides. If anchoring is required, the mattress can be formed into a horizontal apron beside the channel to be anchored by its own weight, or it can be tucked into a ditch in the same manner as a plastic membrane.

Successful mattress filling depends on a continuous supply of grout to the pump(s), so the operation must be organised with sufficient manpower, materials or mixing facilities.

5 Summary and Recommendations

First, the options of sprayed foam and sprayed membrane linings are not recommended at this time, as the chances of a successful installation seem remote.

Thin cementitious renders could have some merit in cases where the main problem with the old lining is erosion or chemical attack, but they are not recommended for large-scale relining in other circumstances.

Of the other options, the best relining method for a particular channel will then depend on a number of factors, all weighed against the cost of the operation.

For instance, a channel in which some movement might occur should receive a flexible lining option such as a plastic membrane, but the very movement which prompts such a decision may well have disrupted the old lining to the point where the exercise of smoothing it becomes very expensive.

Sprayed concrete is relatively inexpensive, but suffers from the same movement and shrinkage cracking as any other concrete, as does grout injected mattress, although apparently to a lesser extent.

It is, of course, possible to install a plastic membrane and then to protect it with a sprayed concrete or mattress layer, but this would be very expensive and only justified for a critical channel when its service life must be extended for a long time.

6 References

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