

Preventing failures in ring tanks

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Building good structures from earth is not new. Over 2500 years ago, in 504 BC, an earth dam 20 metres high was constructed and operated well.

The knowledge of soils and construction methods is well established and readily available — and yet too many ring tanks still fail. We all run on tight budgets, so sometimes compromises are made and risks taken. A better understanding of the risks should enable better design and construction decisions to be made.

A brief look at the history of embankment failure and the factors influencing the failure rate is a good start and is shown in Table 1. A study of the specific causes of failures is also instructive as shown in Table 2.

COSTLY EXERCISE

Ring tanks represent a big investment at around \$215 per metre length of bank for a six metre high embankment built properly. Typical costs would be:

| | |
|-----------------|-----------|
| 500 megalitres | \$270,000 |
| 1000 megalitres | \$385,000 |
| 5000 megalitres | \$860,000 |

With such a large investment, the temptation to save 20 per cent by not compacting is very high. Resist this temptation because the costs of lost water and embankment repairs are also very high.

A GOOD RING TANK

Development of a good ring tank should see:

- A thorough investigation using an electromagnetic survey to establish the pattern of soil type over the site;



3.45pm: The early stages of a break in a storage wall — note the grass roots right through the embankment and the dripline for irrigating grass.

- Several backhoe pits dug in each soil type along the proposed borrow pits;
- At least basic soil classification and testing for dispersive soils;
- A basic seepage test in a pit in the borrow area;
- A survey and design to establish reliable earthworks volumes and to enable good pegging out for construction control;
- A design which defines the cut-off depths and borrow pit locations and depths to prevent leakage;
- Guidance on which soil from the borrow is suitable for the inside, centre and outside zones of the embankment; and,

- Forward planning to ensure the sub-soil of the borrow pits is moist to allow good compaction.

Proper construction would involve:

- All topsoil stripped from beneath the whole bank and borrow areas and placed over the finished embankment;
- A four metre wide cutoff trench cut at least 500 millimetres into good clay under the embankment;
- A central battered core consisting of the best moist clay laid in thin layers of 150 millimetres or less and compacted with a sheepsfoot roller or sheepsfoot compactor at least six to eight times per layer;
- A well finished embankment with good batter control during construction and finish levels checked;
- A carefully installed reinforced concrete or other non-corrosive pipe placed through the embankment with proper compaction around, under and over the pipe which is fitted with at least one or more flexible cutoff collars around the pipe;
- Grass planted on the inside batter to resist erosion from wind waves;
- A clearly marked top water level which allows enough freeboard on the embankment for reasonable maximum wind wave height plus at least 0.5 metres;
- A good maintenance program which



5.20pm: Once the water starts flowing through cracks, failure is quick and hard to stop.

regularly grades — in small erosion rills from rain runoff, keeps grass and weeds off the crest and outside batter — and from recent experience, prevents vigorous grass growth on embankments which are empty for extended periods; and,

- Operation of the ring tank so that it is filled and emptied slowly.

THE RECENT DROUGHT SYNDROME

Because of the extended drought some ring tanks have been empty for between two and four years. During this time there has been enough local rain to allow continued survival of grass on the inside batter.

Some of these grasses have been aggressive tropical varieties like African Star Grass which is good in water and offers good batter protection but will not become dormant in drought like native grasses. These grasses continue to drive roots deeper into the embankment to source moisture for survival. As the grass depletes the moisture, the clay in the bank shrinks and cracks into a block structure.

This process continues and the grass roots go further into the bank and so do the cracks. This sometimes happens under the cover of the grass and is not visible on the surface.

When the river flows eventually come,

TABLE 1: Ring tank failures

| Period | Failure rate | Influences |
|--------|--|--|
| 1980s | 25–30%* | <ul style="list-style-type: none"> • Poor investigation • Poor compaction (dozers) • Dispersive soils |
| 1990s | 10–15% * | <ul style="list-style-type: none"> • Better soils investigation • Better compaction (scrapers) • More use of rollers/compactors on cores • Experience from previous failures |
| 2004 | <ul style="list-style-type: none"> • 20+ ring tanks on Darling Downs • Several close calls Gwydir, Namoi & Macquarie | <ul style="list-style-type: none"> • Extended drought • Vigorous grasses growing on bank • Quick fill |

* Source: Dam Breaking History, Department of Natural Resources, QLD 1997

the embankment is both dry and cracked and the ring tank is filled as quickly as possible to maximise water capture.

This process has certainly occurred in some of the recent embankment failures where grass roots were found right through the bank. But without a detailed inspection of all the 20 plus recent failures on the Darling Downs, it isn't possible to claim this as the only mechanism of failure.

This failure mechanism is likely, however, as most of the embankments that failed:

- Were older ones which had stored water for many years without problems;
- Were empty for several years; and,
- Had vigorous grass growth on the embankments and by necessity had to be filled quickly.

Fortunately, even with this large number of failures, little physical damage to areas



Grass on outside batter also growing into embankment with cracks coming from both sides.



Physical damage outside the embankment is generally relatively small but crop damage from water can be a problem.

<9...STORAGE FAILURE

around the ring tanks was reported with the cost of lost water and embankment repairs being the major damage.

WHAT TO DO WITH A CRACKED EMBANKMENT

Anybody who suspects that their embankment may have these characteristics should take action now. Any grass on the crest or outside batters should be removed and the bank carefully inspected for erosion rills (cuts) or cracks.

Any deep rills should be dug out with a backhoe to solid embankment and filled with moist compacted good clay. Small wacker packers or small sheepsfoot roller attachments on the excavator booms are suitable. Thumping with an excavator bucket is not.

It is vital to remember that dry clay cannot be compacted properly and wet clay cannot be compacted either. Moist clay just before it becomes too wet to work is close to the best moisture for compaction.

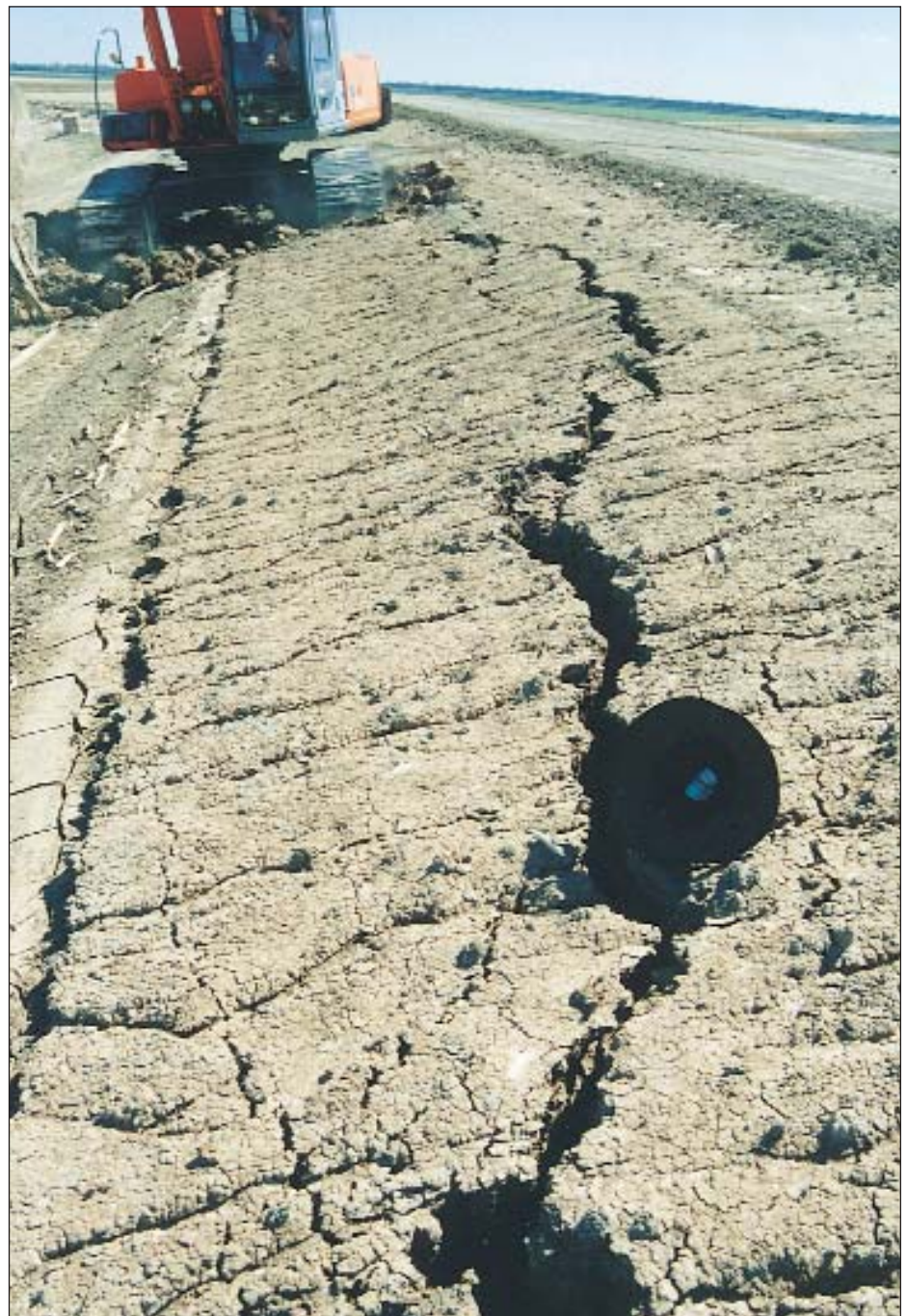
If the embankment has numerous cracks through the top section from drying by grass then this section needs some rebuild-

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TABLE 2: Specific causes of embankment failure

| Mode of failure | % of failures |
|----------------------------------|---------------|
| Tunneling or piping | 60 |
| Along pipes through bank | 15 |
| Poor foundation cut-off | 15 |
| Other | 10 |
| • lamination | |
| • erosion rills | |
| • cracks | |
| Overtopping | Nil |
| Structural failure of embankment | Nil |

Source: Dam Breaking History, Department of Natural Resources, QLD 1997



Settlement on inside batter from initial fill caused poor compaction with dry material.

◁10...STORAGE FAILURE

ing. Water will find its way into the bank through the cracks on filling and if the soil is dispersive (which most sodium rich clays are), tunnels may form which are large enough to allow water to flow.

Once water starts to flow through an embankment, erosion of the tunnel or pipe leads to a bigger hole and failure is quick. If the ring tank is filled slowly, the weight of fill above the tunnel may cause it to collapse and reseal before enough flow causes erosion and enlargement.

To stop this process the cracks must be repaired to prevent a continuous path through the embankment. In the worst case, the top section of the embankment has to be rebuilt using the same material but reworked, laid in thin layers, moistened and compacted.

If the cracking is not as bad, a core in the water side of the crest could be rebuilt with an excavator. Again ensure it is rebuilt



Vigorous grass over the whole embankment. Note cracked blocking structure in the embankment from grass roots.

by placing moist, thin layers and rolling with a sheepsfoot roller attachment on the excavator boom until the roller rides up on top of the layer.



Bank failure along top of pipe through embankment to pumping station. Special care is needed when compacting around pipe. Cut-off collars, preferably flexible, should be installed around pipe

Once the embankment is repaired it is important to carefully watch it for signs of leaks as the ring tank is filled. Stop filling immediately if leaks or slumping is evident and add fresh clay to the inside and allow the bank to settle and collapse any tunneling. If the leak continues, drop some water out of the ring tank and form a new bank on the inside of the leak and repair the bank as above.

MAINTENANCE

It has become evident that continued maintenance of ring tank embankments is more important than we thought.

Keep the crest and outside batters clean of grass and graded regularly to prevent deep erosion rills. If the ring tank is empty, reduce the vigour of the grass by spraying without completely killing it. Remove any deep rooted weeds regularly and do not plant trees on or near earthen embankments.

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