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Guidelines for extraordinary earth dams

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Guidelines for extraordinary earth dams

T F Stephens

INTRODUCTION

Embankment dams for water storage are simple, inexpensive structures ideally designed for use in localities where dry season agriculture is desirable and cheaper sources of water are not available. On good sites a well constructed dam using high quality earthworks material with properly designed slopes, spillways, outlets, etc. will last for many years, require low maintenance, resist earth movements and cost a fraction of an equivalent concrete or similar more sophisticated structure.

The design and construction procedures for earth dams are reasonably well documented (ref 1 and 2) and it is beyond the scope of this paper to detail them. For embankments on technically more difficult sites where the priorities of water storage out weigh the increased risk and expenses, dams can be successfully constructed but with some modification to normal procedures. Brief details for the more common problematical sites follow:

EARTH EMBANKMENTS ON ROCK FOUNDATION

A weir may be a better alternative but where an embankment is required the construction techniques are basically straight forward as long as the points below are adhered to:-

1 The rock available must be solid throughout its length and of sufficient width (not necessarily as wide as the dam base) to provide a good foundation. Minor cracks should be cleaned and loose material removed.

If the dam is of sufficient size in both embankment and storage, the extent of the rock should be ascertained to ensure good seepage cut-off and bearing strength.

2 A key wall should be constructed on the prepared rock base along the proposed wall line (usually at or near the centre of the embankment) to a width and height of 0.75m. Before the bricks, stone or concrete are placed, the rock foundation is prepared with a cement wash (cement and water mixed to a cream consistency) to assist anchorage (anchor bolts and/or cutting of a key trench into the rock is often essential). This wall should wall should not be 100% solid - at regular intervals, gaps should be left that will not structurally weaken it but allow for passage of seepage water.

3 A hearting or central core is now laid (usually by hand) each side of the wall (alternatively this can be placed first to the wall height and a trench excavated in it to rock for the key wall). Following normal techniques, the best clay soil should be used and laid in compacted layers 50-75mm deep. Once the hearting has reached above wall height, placement can continue using machinery and the embankment be constructed as normal.

4 If settlement of the embankment is likely (ie in a high dam or poor earth-works material, differential settlement can fracture rigid key walls) some re-inforcement may be required. Fencing mesh or reinforcing wire placed in the key wall is usually sufficient.

EARTH EMBANKMENTS USING POOR EARTHWORKS MATERIAL

If reasonable clay soils are not available, an embankment can be constructed safely if certain design modifications are followed:-

1 The central core should be placed using the most impervious material available. Antheap can be used as a last resort but must be chemically treated before and during back-filling. Cracking or swelling clays can also be used but it may be advisable to mix them with a coarser soil and then compact properly. In this case the dam owner should be instructed that the dam should be kept as full of water as possible and not allowed to fill up too quickly if the core has dried out, to allow any cracks to seal up.

2 The embankment must have as flat slopes as possible and no steeper than 2:1 for the down-stream side and 2.5:1 for the up-stream. The coarsest material should be laid in the down-stream section of the wall. Settlement allowa-

nce must also be increased at time of construction from the normal 10% to 20% or more.

3 Seepage is always a problem in this sort of dam and risks of damage to the wall can be reduced by installing gravel drains below the downstream face and if, necessary, by "puddling" a clay type "blanket" (100-150mm thick) on the upstream side of the embankment and in the immediate basin area.

Continual maintenance and inspection is essential and most emphasis on this is placed in the first few months after filing up and at subsequent emptying and filling times.

BULLDOZER DAMS

Not recommended as sound and long-lived structures, "dozer" dams can provide cheap and useful ways of storing small quantities of water for purposes of stock watering, water planting, fish farming, garden irrigation, domestic uses and so on.

When using a buldozer, the pushing up of a wall of soil across a water course is not advisable. The better dozer dams are constructed as follows:

1 Maximum height 2.0 m

2 Minimum base width (for above) 11.0m and includes a crest width of 3.0m

3 Foundation cleared of all organic material and top soil to minimum depth of 150mm

4 Material pushed by bulldozer from basin side only and spread in layers up to maximum 150mm deep over complete length of wall.

5 Each layer is compacted using best means available (cattle, tractor tyres full of water, labour using poles, etc.)

6 Side slopes must be no steeper than 2:1 (flatter is better).

If water is expected to spill over the wall, special importance should be given to establishing a good creeping grass cover and maintaining a truly horizontal crest to avoid concentration of floods on any one section.

The "Keying" of dozer dam walls to boulders or anthills is not recommended - seepage and poor anchorage results and termites soon spread into the wall and rapidly cause problems.

Maintenance is again a continual factor and regular inspection, especially after heavy early rains and/or floods, is essential

When dry season water supply is required, the excavation of a deeper section of the basin is a better alternative than raising the wall due to stability problems. Any basin excavation should occur in an area at least 5m from the upstream toe of the wall .

MASONRY CENTRE SPILL DAMS

Centre spillways are normally required when there is no alternative but to spill flood water over the dam wall. For most embankments, the centre spill structure can be based around a gravity weir on rock foundation with headwalls each side to key the spillway to the embankment and safely channel the flood water.

Spilling should be done on rock and suitable provision made downstream to minimise erosion in the streambed. River training through use of stone pitched or concrete channels and gabions may be necessary in extreme cases.

DAMS IN LOW RAINFALL AREAS

Because of climate it may be difficult to establish and maintain a grass cover that is necessary on any earth embankment and spillway to prevent erosion. Therefore, the spillway, if not rock, should be stone pitched throughout with large stones, well wedged on a gravel bed with the long axis of each stone at 90% to ground surface. Any spaces between stones can be filled with a soil-cement mixture or with top soil and planted to a creeping grass if irrigation is possible in the dry season.

The embankment could also be similarly pitched but it may be more economic to stone-pitch places of high risk such as the ends of the wall and wave action areas and then place loose stone or rock on the remainder of the wall. Flatter side slopes should also be adopted at the design stage.

REMEDIAL AND MAINTENANCE PROCEDURES FOR ALL EARTH DAMS

Immediately following construction it is possible that a dam is to be found in its best condition and to prolong its life as much as possible it is vitally important that regular and competent inspection and maintenance of all aspects of the embankment are initiated. Such insepctions should be established on a time-table that will allow for a minimum of one visit a month in the dry season and one visit fortnightly in the rainy season with need for visits immediately after heavy rain or flooding in the first years after construction.

The following points should be made clear to the farmer/owner:

1 Fences

Stock must not be allowed to graze on the embankment, the spillway or its outfall. The dam should be fenced off and all fencing kept in good order.

2 Grass Cover

Short, creeping grasses must be established on the embankment and earth spillway(s) before the rains have the opportunity to erode newly constructed bare earth surfaces. Any bare spots that occur subsequently should be replanted to similar grass.

Long tufted grass should be avoided as they must be kept short and they may conceal the workings of termites and vermin.

Trees and shrubs and their roots must be removed from banks because they can cause leakage, attract termites and, if old and well established before they die, can leave voids in the wall as the roots decompose. Often, if a large tree is allowed to grow on the wall it is better to leave it than attempt to kill and remove it.

3 Erosion

a) Embankment erosion after the first rains is impossible to avoid. It, and erosion in later years must be rectified by ramming grass sods and soil into rills and gulleys as they form.

b) During floods, spillways must be regularly (almost daily) visited and any erosion immediately attended to.

Estimating correct slopes and levelling off of low spots in the dry season, especially in the first few years is essential if the spillway is to perform properly and avoid erosion.

4 Settlement

The crest level should be frequently checked in the early years of its life and at least annually thereafter to ensure that it remains horizontal and that the correct freeboard is being maintained.

Settlement cracks are common after construction and if small should be filled in. Large cracks can indicate movement of the foundation and, with cracks that extend transversely below the water line, should receive expert attention as a matter of urgency.

5 Seepage and Drainage

Virtually all earth dams leak to some extent and seepage only becomes a problem if serious or likely to endanger the embankment.

Any leak should be treated on the upstream side. Puddling clay in the basin or laying a "clay blanket" on the lower upstream face (covered with topsoil to reduce erosion) can assist in reducing seepage.

A sudden leak can be treated by dropping manure and/or wood ash into the water at the suspect location, but again if large should receive expert attention.

Leakage effects on the downstream face can be minimised by drainage in the wall, below it and in the ground immediately downstream. Waterlogging of this section can lead to slumping and, eventually, failure, if the mass is so reduced that it loses its stability.

If at any time seepage water is seen to be flowing out of the downstream face and is dirty it means that piping is occurring in the embankment (i.e. soil is being carried away, in suspension, in the water) and requires urgent and expert treatment.

6 Termites and Animal Burrows

Regular inspection and short comprehensive vegetation cover are essential to keep ant and animal workings under control. Any ant workings found should be suitably treated with a recommended fumigant, dug out and the excavation back filled with good material and chemicals to prevent the return of any termites. All back filling should follow the procedures laid down already with layers no more than 50 to 75mm thick being well compacted and, if the excavation is large, keyed into the surrounding embankment.

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