SA Water

SOUTH AUSTRALIAN WATER CORPORATION

TG 10b

TECHNICAL GUIDELINE

GENERAL TECHNICAL INFORMATION FOR GEOTECHNICAL DESIGN

~ Part B ~
Earth Dam Design

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No Changes Required In the January 2007 Edition

The following lists the major changes to the November 2004 edition of TG 10b:

1. Nil

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Section 1: Scope

Section 2: Shear Strength Parameters

2.1 Background

The first version of the following notes was prepared during the Hope Valley Dam investigations.

You will recall that the ERP and designers considered the approach to be valid, and so the shear parameters eventually used in the analysis were obtained by carrying out triaxial tests on “reconstituted” triaxial samples prepared by blending bulk samples of “matrix” material selected from pits. The triaxial samples were compacted to in situ density. In other words we treated the dam simply as a “quarry” and followed the normal “design” process.

2.2 Earth Dam Design

The design of the embankment of an earth dam is not a rigorous science, despite the fact that it includes apparently precise analytical steps at several stages.

a. The process is approximately as follows:

b. Identify potential borrow pits

c. Determine how much of each material there is available

d. Take representative samples of each material

e. Prepare specimens compacted to the densities to be specified for construction

f. Run triaxial tests to obtain saturated effective shear parameters

g. Design the embankment to fit the materials (geometry, zones, drainage, etc)

h. Check slope stability (static, dynamic, rapid drawdown, etc)

i. Repeat (f) and (g) as necessary until the “required” factors of safety are met.

Dams designed by this process, to the accepted factors of safety for steady seepage, earthquake, etc, are known to have a good chance of not failing. But this “success” is based more on the observation of the past performance of earth dams designed by this process and to these factors of safety, than it is on the accuracy of measurement of parameters and the rigorousness of the analytical

models used. I.e. there is a lot more bundled into those factors of safety than there would be in say structural engineering.
What the design philosophy does NOT say is:

a. That the materials in the dam finished up with the same shear strength parameters as were obtained from the test samples;

b. That the materials in the dam ever will become saturated;

c. That the simplified models used in the stability calculations truly represent conditions in the dam (for example, most earth dams are short and diamond shaped in plan, not long embankments as the models assume); or

d. That the computed factor of safety is the “real” factor of safety.

Earth dam design must therefore be considered, in large part, to be an empirical ***process*** that depends for its validity not just on the assumptions inherent in each stage, but also on a standard ***sequence*** of steps being followed. This being the case, one is not free simply to jump into the design process at any step – it must be followed through.

Therefore great care must be taken when evaluating an existing dam, as the temptation would be to (try to) measure the shear strength parameters of the material ***actually in the dam*** and plug them directly into the stability calculation models. Apart from the difficulty of obtaining representative samples – particularly from old “hand built” dams (more on that later) – such an approach would run counter to the need to follow the basic sequence.

It was probably just such a philosophical misconception that led to early EWS triaxial shear strength tests, on samples recovered from existing dams, being run at their in situ degree of saturation. The logic was that these results would be the *true* shear strength parameters of the material in the dam. This may be so, but unfortunately it would seem that the design process does not require the *true* shear strength parameters, only the *design* ones.

Hence I not only concur with the accepted wisdom that all triaxial tests on material from existing dams should be run saturated, but consider that the design/analysis process <u>demands</u> it and, moreover, that only <u>remoulded</u> shear strength parameters (not “aged” in situ ones) be determined and used in analysis.

2.3 Variability of Materials In Old Dams

Most of the dams in SA on which we have done safety reviews over the years were built in the late 1800s or early 1900s. The design philosophies and construction techniques of the time meant that the materials tended to be won from several different sources simultaneously, especially for the downstream shoulders, and were placed in a similarly random fashion cartload by cartload.

So the most obvious feature of the trial hole logs for the downstream shoulders in such dams is, not surprisingly, their variability.

This variability can continue down to the scale of individual triaxial samples -- a typical description of a sample being "mixture of sand, clay and stone, multicoloured, moist, firm".

Variability – in both the materials themselves and in the properties of those materials – is so much the dominant characteristic of these dams, that when preparing the "Report on the Field Work and Laboratory Testing for the Happy Valley Dam, February 1977", I considered that it would be best to present the data in such a way as to visually illustrate this variability rather than to try to give an estimate of typical values for the various parameters.

That way, subsequent users of the data would be forced to be aware of the variability and of the assumptions they were making when they themselves attempted to extract "typical values" for stability analyses etc.

In summary, the analytical methods used in earth dam design do not want “in situ” shear strength parameters they want “design” (i.e. remoulded) values, and furthermore the variability in old dams prevents the recovery of representative samples. It would therefore seem that a program of sophisticated triaxial testing on undisturbed samples (particularly if won from the downstream shoulder of an old dam) is at best an expensive act of self-deception.

2.4 Using Reconstituted Remoulded Material For Determining Shear Strength Parameters For Existing Dams

All of the foregoing discussion leads to the conclusion that the best way to check the stability of an existing dam is to follow the same procedure as would be used for the design of a new dam. In other words simply treat the existing dam as a “quarry”, and then follow through the design procedure. This would involve the following steps:

1. Study any original design drawings and construction records, and the logs of all trial holes and (ideally) pits, to determine how the dam was zoned and what the typical “matrix” material is in each zone.

2. Assess or determine the in-situ density of each typical material/zone.

3. Obtain several bulk samples of each typical “matrix” material, and blend and screen them as required for the preparation of triaxial test samples. (Ideally these should be won from pits but could be obtained from samples recovered from trial hole.).

4. In compaction moulds, compact the blended material to the estimated/observed in situ densities.

5. Cut triaxial and/or direct shear test specimens from the compacted samples and carry out the triaxial and/or direct shear tests.

This approach was successfully followed for the SA Water Hope Valley Dam Safely Evaluation and is written up in reports entitled “Preliminary Pitting Investigation – April 1997 – Data Report and Supplement to Data Report”.

This “Technical Note” was prepared by Ed Collingham, 06/02/2002
(Ex Principal Engineer Geotechnical)

Section 3: Height of Dams VS Storage

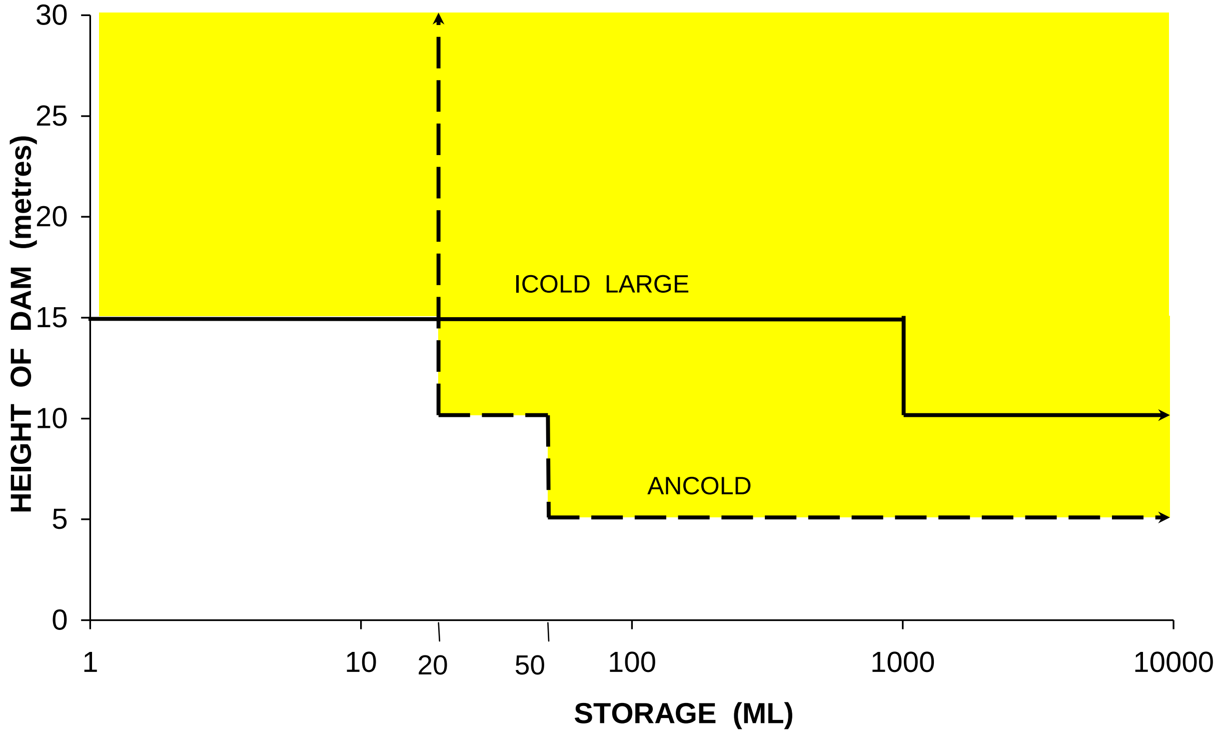

Figure 3.1 - Height of Dams VS Storage

This "Technical Note" was prepared by Ed Collingham, 03/06/2002
(Ex Principal Engineer Geotechnical)