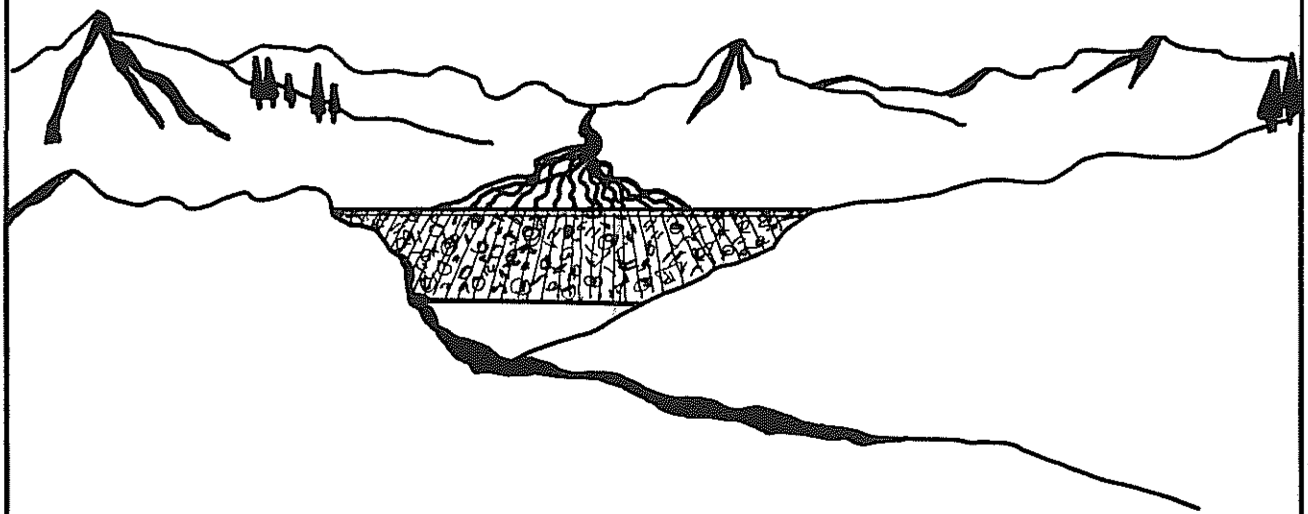
GENERAL GUIDELINES FOR THE DESIGN OF SMALL HOMOGENEOUS EARTHFILL DAMS



Waikato Catchment Board

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WAIKATO VALLEY AUTHORITY TECHNICAL REPORT 1987/24

GENERAL GUIDELINES FOR THE DESIGN OF SMALL HOMOGENEOUS EARTHFILL DAMS

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1.0 INTRODUCTION

These guidelines outline requirements for small earth dams (height less than 15 metres) that do not require special design.

2.0 FOUNDATIONS

The essential requirements of a foundation for an earthfill dam are that it provides stable support for the embankment, and that it provide sufficient resistance to seepage.

The minimum treatment for any foundation will require the stripping of the foundation area to remove sod, topsoil with organic content and other unsuitable material. In all foundations a key trench should be used to bond the embankment material to the foundation.

2.1 Rock Foundations

Foundations of rock generally do not present any problems of bearing strength for small dams. Rock foundations should however be investigated to determine their permeability. If erosive leakage, excessive uplift pressure or high water losses will occur through joints, fissures, crevices, permeable strata, or along fault planes the foundation should be grouted.

2.2 Sand and Gravel Foundations

These require special consideration pertaining to minimising seepage volumes and forces and are not dealt with here.

2.3 Silt and Clay Foundations

2.3.1 Design for Saturated Foundations

The construction of small dams on saturated fine grain soils may require the addition of stabilising fills to the shoulders of the dam embankment as shown in Figure 1 and Table 1 depending on the consistency of the foundation soil and its classification according to the United Soil Classification System. These requirements are based on a factor of safety of 1.5 and average embankment properties.

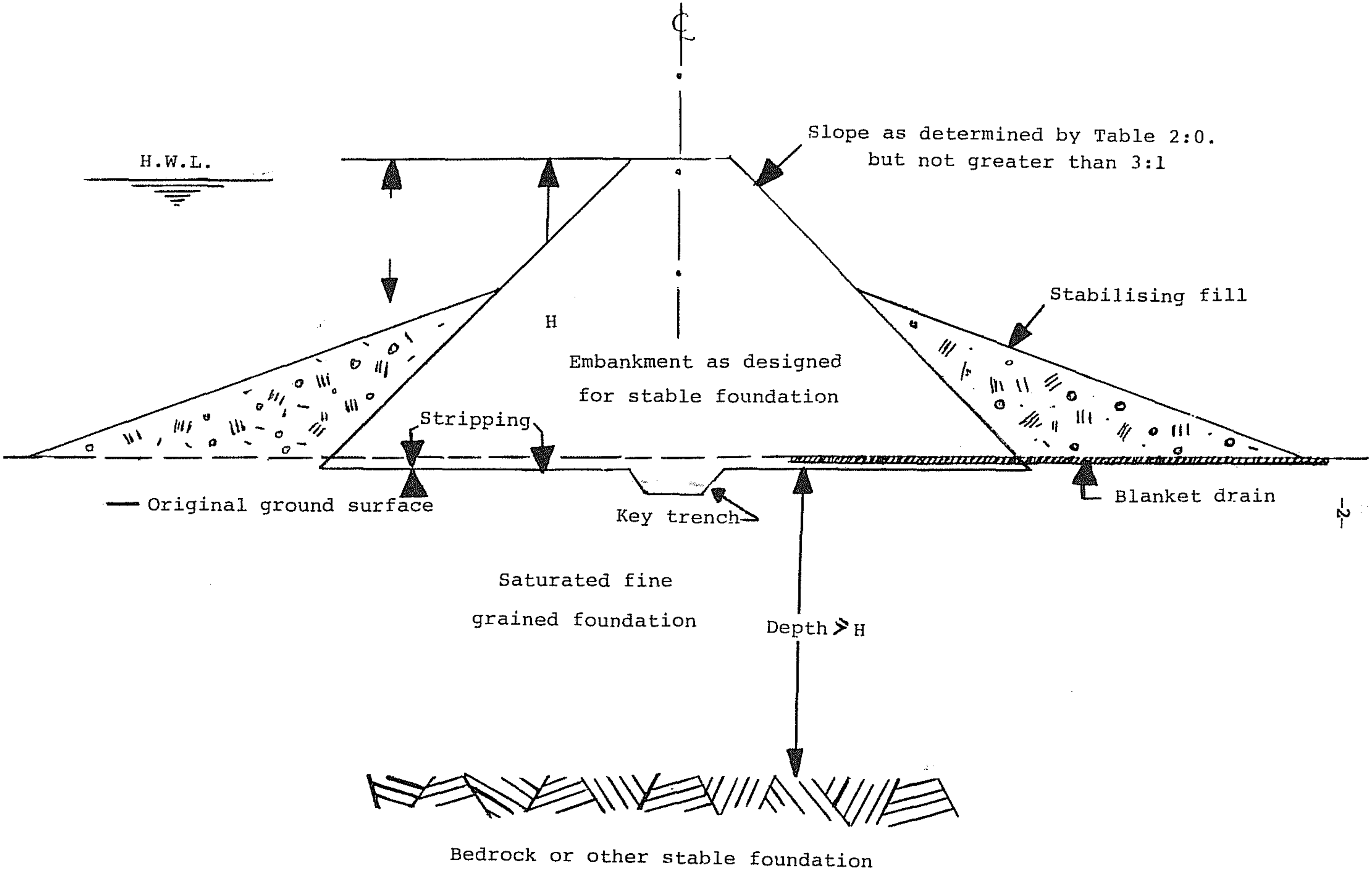

Figure 1:0. Design of dam on saturated fine grained foundation

Table 1:0. Recommended slopes for stabilising fills on saturated silt and clay foundations.(Taken from "Design of Small Dams",U.S. Department of the Interior Bureau of Reclamation.)

CONSISTENCY OF SOIL	STANDARD PENETRATION TEST "N" VALUE	FOUNDATION SOIL CLASSIFICATION (1)	SLOPE OF STABILISING FILL FOR VARIOUS DAM HEIGHTS				
			15 m	12 m	9 m	6 m	3 m
Soft	Less than 4	Special soil tests and analyses required					
Medium	4 to 10	SM	4.1:1	4:1	3:1	3:1	3:1
		SC	6:1	5:1	4:1	3:1	3:1
		ML	6:1	5:1	4:1	3:1	3:1
		CL	6.5:1	5:1	4:1	3:1	3:1
		MH	7:1	5.5:1	4.1:1	3.5:1	3:1
		CH	13:1	10:1	7:1	4:1	3:1
Stiff	11 to 20	SM	4:1	3.5:1	3:1	3:1	3:1
		SC	5.5:1	4.5:1	3.5:1	3:1	3:1
		ML	5.5:1	4.5:1	3.5:1	3:1	3:1
		CL	6:1	4.5:1	3.5:1	3:1	3:1
		MH	6.5:1	5:1	4:1	3:1	3:1
		CH	11:1	9:1	6:1	3:1	3:1
Hard	More than 20	SM	3.5:1	3:1	3:1	3:1	3:1
		SC	5:1	4:1	3:1	3:1	3:1
		ML	5:1	4:1	3.5:1	3:1	3:1
		CL	5:1	4:1	3:1	3:1	3:1
		MH	5.5:1	4:1	3:1	3:1	3:1
		CH	10:1	8:1	5.5:1	3:1	3:1

(1) United Soil Classification System

NOTE: Stabilisng soils are not needed when embankment slopes listed in Table 2 are less than those listed above.

2.3.2 Relatively Dry Foundations

Generally unsaturated impermeable soils are satisfactory for foundations of small dams. There is however a group of soils which have low densities and may be subject to collapse when saturated by the reservoir. A typical example of these is loess type soils.

The design of dams on deposits of dry foundations of low density must take into account the possibility of settlement on saturation by the reservoir. To determine whether these soils are susceptible to excessive settlement requires knowledge of the difference between natural water content and optimum content, and percentage of the Proctor maximum dry density existing in the natural soil. An empirical relationship between D (inplace dry density divided by Proctor maximum dry density) and WO-W (optimum water content minus in place water content) is shown in Figure 2. An alternative criteria in terms of natural dry density and liquid limit for use in the absence of Proctor test facilities is shown in Figure 3. For foundations of unsaturated soils that fall into the "no treatment required" category only the usual foundation stripping and key trench are required. Soils with inplace water content considerably greater than WO should be checked to determine the degree of saturation. If they are over 95% saturated they should be considered as saturated and designed accordingly.

3.0 EMBANKMENT STABILITY

The slopes of the embankment must be stable during construction, and under all conditions of reservoir operation, including rapid drawdown of the water surface. Recommended embankment slopes for small homogeneous earthfill dams on stable foundations are shown in Table 2.

4.0 CREST WIDTH

A minimum crest width should be that width which will provide a safe percolation gradient through the embankment at the level of a full reservoir. Because of practical difficulties in determining this factor the crest width is as a rule determined empirically and the following formula is recommended for small earth fill dams:

$W = H/5 + 3$ m where: W = dam crest width

H = dam height

Table 2:0. Recommended slopes for small homogeneous earthfill dams on stable foundations
(Taken from "Design of Small Dams" U.S. Department of the Interior Bureau of Reclamation.)

SUBJECT TO RAPID DRAWDOWN	SOIL CLASSIFICATION (1), (2)	UPSTREAM SLOPE	DOWNSTREAM SLOPE
No	GW, GP, SW, SP	Pervious, not suitable	
	GC, GM, SC, SM	2.5:1	2:1
	CL, ML	3:1	2.5:1
	CH, MH	3.5:1	2.5:1
Yes	GW, GP, SW, SP	Pervious, not suitable	
	GC, GM, SC, SM	3:1	2:1
	CL, ML	3.5:1	2.5:1
	CH, MH	4:1	2.5:1

(1) United Soil Classification System

(2) OL and OH soils are not recommended for major portions of homogeneous earthfill dams and Pt soils are unsuitable.

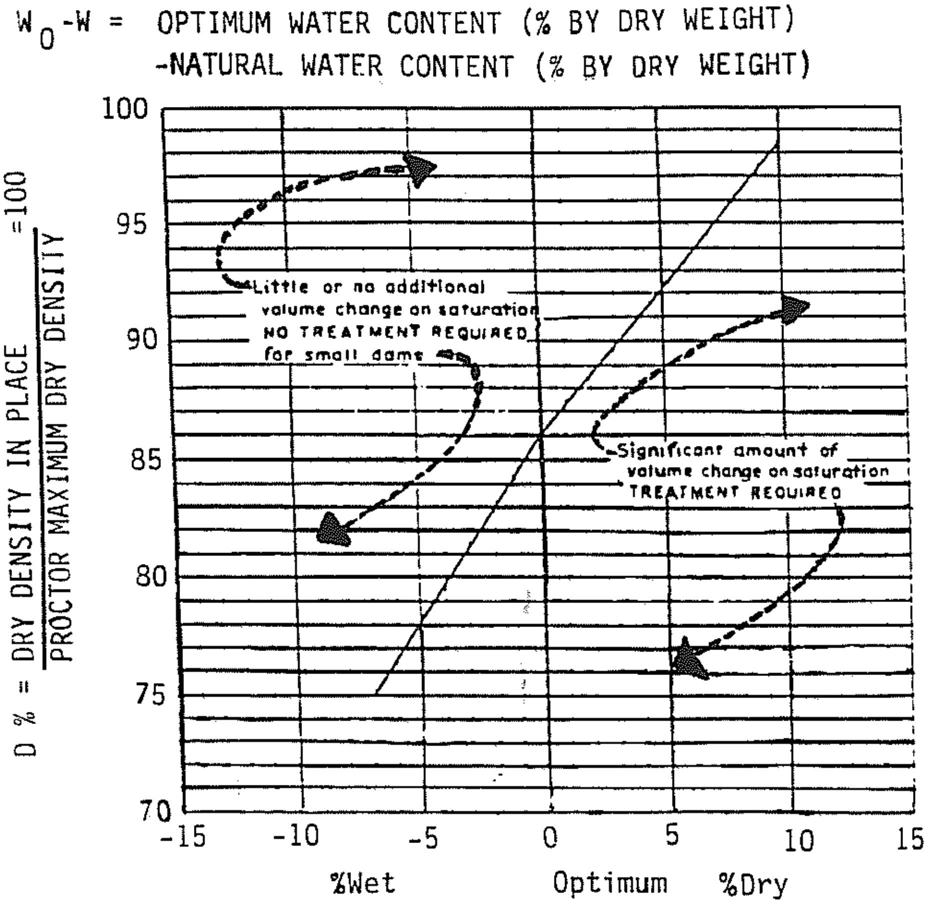

Figure 2:0. Foundation design criteria for relatively dry finegrained soils

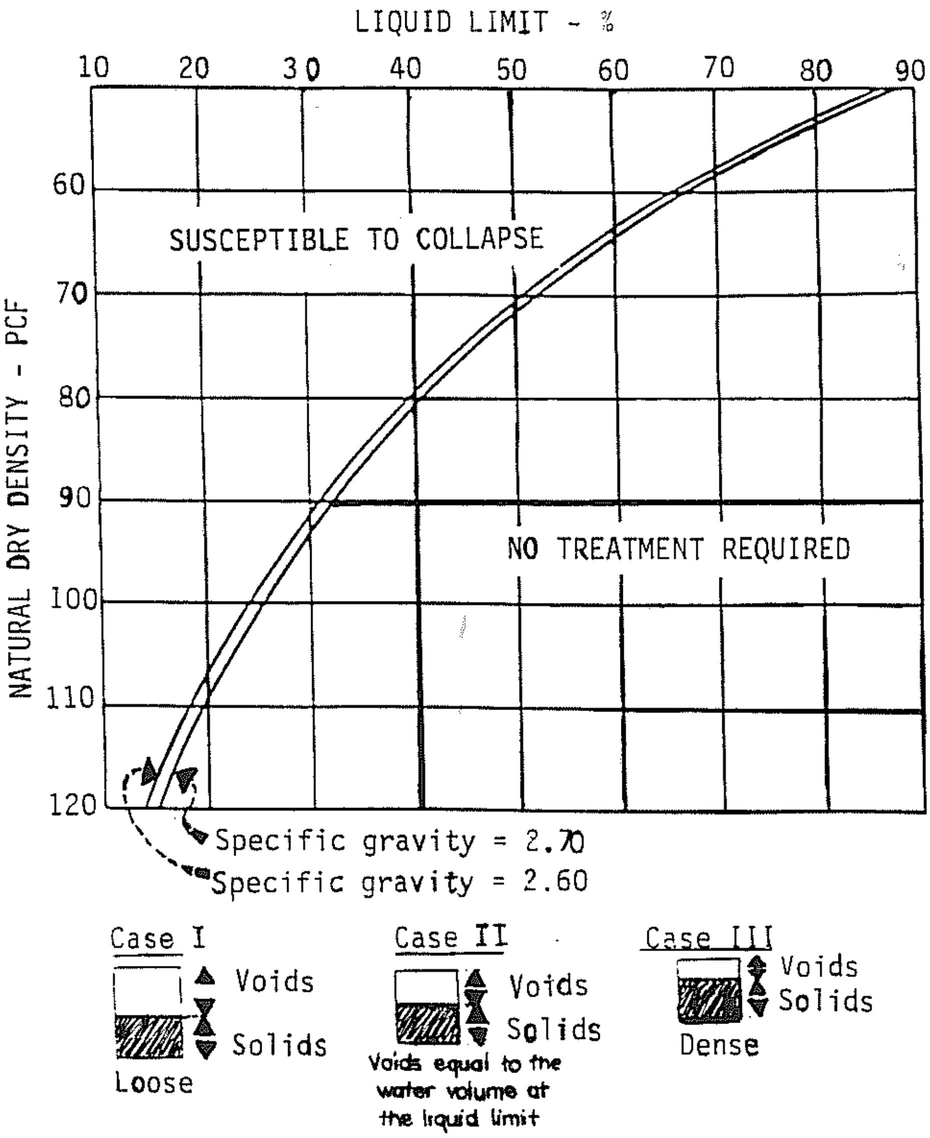

Figure 3:0. Alternate foundation design criteria for relatively dry fine grained soils
(Adapted from Gibbs 1966)

5.0 EMBANKMENT SEEPAGE

Seepage flow through the embankment must be controlled so that no internal erosion takes place and so that there is no sloughing in the area where seepage emerges. Specific forms of seepage control may vary but would normally take the form of a horizontal blanket drain or a toe drain. Both types of drain should include a filter to prevent clogging with eroded fines from the dam. Blanket drains should extend from the tow of the dam to within H + 1.5 m of the dam centreline (H = dam height).

Seepage control drains will nor normally be necessary if the reservoir will not contain water for any significant length of time (ie. the phreatic surface will not have time to develop). For example, flood detention dams would fall into this category.

6.0 SPILLWAY DESIGN

The dam spillway should normally be capable of passing a 100 year flood while maintaining a minimum freeboard on the dam of 300 mm. For spillways incorporated in the dam embankment velocities over the crest and on the downstream slope should not be sufficient to cause erosion. For this reason the crest and downstream slope of an embankment spillway should be well grassed.

As a typical example design for a spillway with crest 0.5 m below the dam crest and design discharge Q is set out as follows:

Maximum head on spillway H	= 0.2 m (300 mm freeboard)
Critical depth at crest Y	= 2/3 x 0.2 = 0.133 m
Critical flow over crest q	= 0.152 m^2/sec.
Critical velocity over crest V	= 1.14 m/sec.
Required length of spillway L	= Q/0.152

Check velocities on downstream slope by Manning equation

Roughness n	= 0.05
Maximum allowable velocity (say)	= 2.0 m/s
Maximum flow depth Y = q/V	= 0.152/2.0 = 0.076 m
Maximum slope S	= 0.310 (say 1:3)

For higher heads on a grassed spillway then the slope of the downstream embankment would need to be decreased to ensure lower velocities.

7.0 UPSTREAM SLOPE PROTECTION

The upstream slope of the embankment may require protection against erosion due to wave action if the reservoir is large. This should take the form of rock rip-rap, rock filled reno mattresses or some other suitable form of protection and should extend from a safe distance (several feet) below minimum water level to a similar distance above normal maximum operating level. Above this level the embankment should be maintained in grass.

8.0 COMMENTS ON DAM CONSTRUCTION AND MAINTENANCE

It is essential that good construction practices be employed when compacting fill. Ideally fill should be compacted in shallow layers close to optimum moisture content. The maximum layer thickness will depend to a large extent on the characteristics of the material being compacted, the type of compaction equipment used and the amount of compactive effort applied. For typical non specific design situations where no specialist compaction plant is available a layer thickness of between 150 mm and 300 mm is considered reasonable. Where fill that has a moisture content significantly greater than optimum (ie close to saturation water content) is being placed construction should be undertaken in stages to allow time for dissipation of excess of pore pressures.

It is important too that the slopes and crest of the embankment are well vegetated and that the spillway is well maintained. The embankment, abutments, and visible portions of the foundation adjacent to the embankment should be checked periodically, particularly during the first 1-2 years of operation, for evidence of the development of unfavourable conditions. Observation of the embankment and the adjacent foundation is most critical at times of rapid filling or drawing down of water levels. Particular items to look for include cracks, slides, sloughs, subsidence, impairment of slope protection, springs, seeps, or boggy areas caused by seepage from the reservoir.

The outflow from blanket drains or toe drains should also be checked from time to time as any sudden increase or decrease in volumes may provide early warning of problems with seepage control. Any increase in fine material in the outflow may also warn of internal erosion.

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