WATER STORAGE SEALING- PERMEABILITY & BENTONITE

Irrigation and water storage is a major issue in Australia and reducing wastage through seepage is an essential feature of preserving this valuable resource.

Arumpo Bentonite is ideally suited to dam sealing and, applied as a blanket or in admixture with the local clay, provides an economical means of creating high performance dam linings. The unique sealing properties of Arumpo bentonite are associated with its extremely fine natural grain size, relatively modest swell and moderate liquid limit.

Arumpo Bentonite has a very low permeability and decreases further at higher heads. Applied at a low dose rate Arumpo Bentonite can reduce dramatically local clay permeability.

The behaviour of every soil system is different. Gravels and sands have high permeability and silty clays are low. It is therefore important to classify the soil to be used and know its permeability. This can be identified from drill samples across the dam profile by test. Laboratory testing, simple in situ trench methods, or the testing of soil or soil – bentonite mixtures using drums to measure the rate of water penetration through a 10cm barrier, are all applicable. These should preferably be conducted by a person experienced or qualified in the techniques.

There is substantial information available in the construction of earth dams for water storage. For example, publications by the relevant State Agricultural Departments can be helpful (eg. “Leaking Farm Dams” NSW Agriculture Agfact AC.24 1997). Criteria for soil definition, properties and testing are provided by the relevant Australian Standards AS 1289.1 to AS 1289.7. Testing can be performed by a number of NATA registered geotechnical testing laboratories around Australia.

Whether the dam is fully evacuated, part evacuated (“turkey’s nest”) or confined by a retaining wall, the most important factors are to ensure that the structure is ideally located, and that the material removal is planned ensuring that better clays or clay soils are used in the barrier layers.

Permeability and water loss

A permeability value for the dam lining of 10^{-8} m/sec or less is highly desirable.

For example Table 1 shows seepage losses for a 50 megalitre dam. A permeability of 10^{-8} m/sec results in a seepage loss of 6% per year. Lower values are preferable, as undue seepage not only causes losses, but can also allow the development of failure paths.

Table 1. Seepage Rates Versus Permeability

Dam lining permeability (m/sec)	Time to penetrate 10 cm	Seepage loss (‘000 litres/month)*	Seepage loss per year (%)
1×10^{-6}	28 hours	26,000	
1×10^{-7}	12 days	2,600	62%
1×10^{-8}	3.9 months	260	6.2%
1×10^{-9}	3.2 years	26	0.6%
1×10^{-10}	32 years	2.6	0.06%

***for a dam 100 x 100 m^2, 1 in 3 wall slope, 11m deep and 0.5 m freeboard (~ 50,000 m^3 capacity)**

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Soil classifications and likely dose rates for bentonite addition

Table 2 gives the broad soil classifications and the estimated bentonite dose necessary to give an adequate barrier. Experience shows that the performance of soils even within a classification can be very different, depending on factors such as the size distribution and proportion of fines, dispersability, and rheological properties of the particular clay or soil.

Table 2. Soil Type And Bentonite Dose

Major Soil Divisions	Soil classification subdivisions	Estimated bentonite addition, % of dry wt soil	Amount of bentonite addition, kg/m^2 (150 mm barrier depth)
Gravels, gravel-sand mixtures	GW, GP,	10 - 20	15-30
Gravel –sand mixtures with some clays or silts	GM, GC	10 - 20	15-30
Clean sands, low fines	SW, SP	10 - 15	15-20
Sands with silt or clays	SM, SC	5 - 10	7-15
Silts and clays, very fine sands	ML, CL	5 - 10	7-15
Organic clays and silts, peaty soils	CI, OL, MH, CH, OH, Pt	Unsuitable for dam use	NA

Arumpo Bentonite has a very low permeability (10^{-10} m/sec at a water head of 4 metres) and decreases further at higher heads. Applied at a 10% dose rate Arumpo Bentonite can reduce local clay permeability to close to 10^{-9} m/sec . At a 10% dose rate mixed with soil, or as a 12mm thick blanket, ~150 tonnes of Arumpo bentonite will be required for a dam 100 x 100 m.

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Examples of permeability and treatment with Arumpo Bentonite -

The performance of some bentonite treated clays is given in Table 3 (Mildura region). These clays were considerably improved by admixture of 10% bentonite. Even road base, which has a graded size distribution of crushed rock from 20 mm downwards, and in which successively smaller size fractions infill the voids in those above, can be successfully treated with a very low dose, 1%, of Arumpo bentonite.

Table 3. Permeabilities of various clay and gravel types mixed with Arumpo bentonite

Soil type	% fine grade	Permeability		Product mixture	
		Soil alone	Soil + 10% bentonite	Liquid limit wt %	Plasticity index, %
Road base aggregate	~12	3×10^{-5}	1×10^{-8} (1% bentonite)		>2 &<8
Clayey sand, SC (Buronga 2)	44	4×10^{-8}	5×10^{-9}	36	25
Sandy clay, CL (Merbein 1)	68	1×10^{-8}	3×10^{-9}	37	24
Clayey sand, SC (Yatpool 3)	56	1.5×10^{-8}	4×10^{-10}	32	21
Arumpo bentonite	-	1×10^{-10}	-	123	64

Laboratory measurements, 4 m hydraulic head

The effect of increasing additions of bentonite on the permeability of a particular clayey sand (Buronga, Table 2) is shown in Figure 1. The permeability decreases logarithmically with bentonite addition and a small increase in dose has a substantial effect on performance. Comparable trends could be expected for other clays.

Figure 1. Permeability vs bentonite addition for a clayey sand