

SOS (slurry or slime)?

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Abstract: Soft slurry slime is found at the bottom of many mined-out ponds in the Kinta Valley. Haphazardous reclamation of these ponds has often led to ground settlement problems, resulting in the formation of cracks in buildings built over such reclaimed ground. The terms 'slurry' and 'slime' are often used interchangeably to describe the soft fine residues derived from the washing of placer tin-ore deposits. Based on results of Mackintosh Probes, Shear Vane tests and the study of solids concentration in the slurry slime of eight ponds in the Kinta Valley, a new classification system to distinguish 'slurry' from 'slime' is proposed.

INTRODUCTION

Malaysia was the largest producer of tin in the world until recently, when depressing tin metal prices forced the closure of many mines, leaving behind hundreds of abandoned ponds. Soft slurry slime is found at the bottom of many of these ponds and haphazardous reclamation of these ponds for the purposes of developing into housing or industrial estates has often led to ground settlement problems, resulting in the formation of cracks in the buildings.

The terms 'slurry' and 'slime' are often used interchangeably to describe the soft fine residues derived from the washing of placer tin-ore deposits and found at the bottom of the mined-out ponds. There has been no clear-cut definition of these two terms 'slurry' and 'slime' and as such, a classification, based on shear strengths, solids concentration (defined as the dry weight of a sample over its wet weight) and Mackintosh Probe values would be useful to engineers.

PRESENT CLASSIFICATION OF SLURRY SLIME

Yong (1985) pointed out that there are four basic compositional constituents of dispersed particulate systems. These compositional constituents are:

- i) inorganic solids consisting primarily of mineral particles and amorphous materials.
- ii) organic and humic materials.
- iii) dissolved and undissolved electrolytes.
- iv) micro-organisms.

Yong (1985) contended that slimes contain primarily groups (i) and (iii) whereas slurries, which are akin to slimes, may contain group (iv) as well. Sludges, on the other hand, contain all four groups. However, there is no

mention of any difference in the engineering properties of the slimes, slurries and sludges.

Mohamad & Nicholls (1990) used the term 'slurry' and 'slime' interchangeably and described slurry or slime as materials having a shear strength below 40 KPa (4.1 tonne/m²)

Yee (1990) described slime as extremely soft clays with SPT (Standard Penetration Test) 'N' values varying from 0 to 2 and having an undrained shear strength of 0 to 15 KPa (0 to 1.54 tonne/m²). Slurry however, was not defined.

Tan and Yeap (1987) classified buried slime as having JKR (Jabatan Kerja Raya) Probe values of less than 20 blows for 300 mm penetration or having CPT (Cone Penetration Test) values of less than 1 kg/cm² (98.07 KPa). The term slurry, again was not defined.

The Concise Oxford Dictionary (1982) defines slurry as "a thin liquid cement, a suspension of fine solid material in liquid, or a thin mud" and slime as "an oozy (sluggish flowing) mud". These definitions give the impression that slurry is in fact, of lower consistency than slime and as such, there should be a difference in their solids concentration, shear and bearing strengths. In fact, in the mining fraternity, it is commonly accepted that slurry is composed of a fluid mixture of solids (minerals and tailings) and water, and most important of all, is pumpable. Slime, on the other hand, is the solid component that has settled out from a slurry system (Chow, 1998).

The writers have conducted Mackintosh Probes, Shear Vane tests, and solids concentration studies on slurry slime in eight selected ponds in the Kinta Valley (Table 1). Based on the solids concentration, shear strengths and bearing strengths of the slurry slime, the writers propose a classification system for the 'slurry' and 'slime' of Malaysian tin-mine ponds.

METHOD OF INVESTIGATION

To study the strengths of slurry and slime in ponds, *in-situ* Mackintosh Probe and Shear Vane tests were conducted

Note: Solids concentration = $\frac{\text{Dry weight}}{\text{Wet weight}} \times 100\% = \frac{W_d}{W_t} \times 100\%$

W_d = dry weight of sample

W_t = wet weight of sample = $W_d + W_w$

W_w = weight of water in sample

Table 1. List of ponds with *in-situ* Mackintosh Probe and Shear Vane tests conducted.

Pond Number	Mukim	Mining Method	Longitude	Latitude	Bedrock Geology
E814	Kampar	Palong	101° 7' 37.20"	4° 19' 13.46"	Limestone bedrock
B72	Tg. Tualang	Palong	101° 4' 14.43"	4° 20' 11.39"	Limestone with schist lenses
B20	Tg. Tualang	Palong	101° 3' 18.23"	4° 24' 50.12"	Limestone
B141	Teja	Palong	101° 5' 26.58"	4° 22' 3.04"	Limestone
B81	Tg. Tualang	Palong	101° 2' 30.38"	4° 20' 48.60"	Schist with limestone lenses
B122	Tg. Tualang	Palong	101° 4' 51.64"	4° 21' 46.35"	Limestone with schist lenses
B127	Teja	Dredging	101° 5' 0"	4° 20' 51.03"	Limestone
B5	Tg. Tualang	Dredging	101° 3' 25.06"	4° 24' 28.86"	Limestone

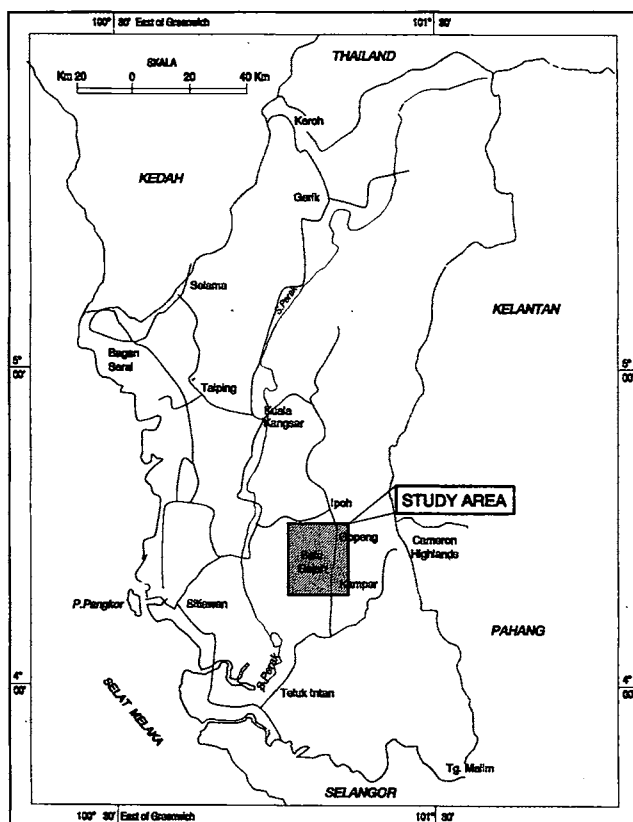


Figure 1. Location of study area.

on eight selected ponds in the Kinta Valley (Fig. 1). Five of the ponds (Ponds E814, B72, B20, B141 and B81) are left-overs of the palong method of mining and the remaining three (Ponds B122, B127 and B5), are abandoned dredged ponds. These eight ponds also have different types of bedrock geology (Table 1).

To conduct Mackintosh Probe and Shear Vane tests in the ponds, two fibre-glass boats were tied together with a wooden platform in between. At the center of the platform is a hole for the lowering of the Mackintosh Probe and Shear Vane to determine the bearing and the shear strengths of the slurry slime, respectively. To study the solids concentration of the various slurry slime strata, a slime bailor with connecting sampling rods was lowered into the pond. The slime bailor, which has a diameter of 7.5 cm (3.0 inches) has 3 internal valves which allow the slurry slime to enter when the bailor is pressed downwards. However, when the bailor is raised, the valves close

automatically to retain the slime. The slurry slime which was collected was packed in air-tight bags and sent to the laboratory immediately for analyses of the solids concentration.

GENERAL SLURRY SLIME PROFILE IN PONDS

Yong (1985) studied the gravitational settling of tailing wastes in sedimentation ponds where four distinct zones were demarcated (Fig. 2). Zone A is a layer of supernatant with very little suspended solids and is clear. Beneath this is a transition layer, referred to as Zone B, where the water is murky. Further down is a stagnant zone (Zone C) where the clayey particles form a thick suspension. At the bottom of the pond, the clay particles undergo some degree of compaction (Zone D).

Investigations carried out by the writers showed that most ponds that have been left undisturbed for a year or more will have a distinct Zone A. Underlying this is a very thin Zone B where the water is murky with about 10 to 20% solids concentration. This Zone B is usually about 30 cm (1 foot) thick. Further down is Zone C where the clayey particles form a thick suspension with solids concentration varying between 30% to 40%. At the bottom of the pond, the clay particles undergo some degree of self-compaction and generally have solids concentrations above 40% (Zone D).

RESULTS OF INVESTIGATION

Ponds from the dredging mining method

Investigations showed that the water in the three dredging ponds B122, B5 and B127 were shallow, varying between 1.8 m to 2.1 m in depth (Fig. 3). Just below the water was a layer of very soft slurry slime where the Mackintosh Probe rods sank under their own weight. This layer varied from 2.9m in Pond B127 to 6.6 m thick in Pond B5. Underlying this very soft layer is a thin layer of about 0.7 m to 1.2 m where there was penetration under the combined weights of the Mackintosh Probe rods and hammer. Further down, the Mackintosh Probe values varied between 7-64 blows per 30cm penetration for Pond B127, 12-78 blows per 30 cm for Pond B122 and 8-57 blows per 30 cm for Pond B5. The basal sections of the three ponds

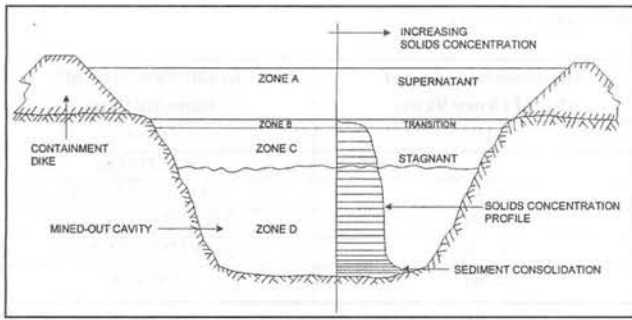


Figure 2. Idealized profile of sedimentation pond.

were underlain by interbeds of slurry slime and sand with Mackintosh Probe values reaching up to 124 blows per 30 cm penetration.

The Shear Vane tests showed that the uppermost 1.3 m to 1.9 m section of the profile (the portion just below the water where slurry slime is present) has no shear strength at all. Below this, the slurry slime is more compact, having shear strengths of up to 3.7 tonne/m². The basal section of interbedded slurry slime and sand had higher shear strength readings, but some of these readings in fact did not reflect the true shear strength, but were due to friction between sand grains.

The solids concentration of the slurry slime increased with depth, varying between 32% at the uppermost portion to about 58% at the bottom.

Ponds from the palong method of mining

Investigations showed that the water depths in the five ponds (Ponds E814, B20, B72, B81 and B141) derived from the palong method of mining were very shallow, varying between 0.6 m to 1.8 m (Fig. s4 and 5)

Below the water, Mackintosh Probe tests showed that there was a thick layer of very soft slurry slime varying between 1.7 m to 3.7 m where the rods of the Mackintosh Probe sank under their own weight. Beneath this was a thinner layer of 1.0 m to 1.8 m where there was free penetration under the combined weights of the Mackintosh Probe rods and the hammer. Further down, the slurry slime had Mackintosh Probe readings varying from 6 to 93 blows per 30 cm penetration. The basal sections of the ponds were underlain by sand which had Mackintosh Probe readings of up to 120 blows per 30 cm.

Shear Vane tests showed that the uppermost 0.9 m to 3.1 m section of the profile (where slurry slime is present just beneath the water) had no shear strength at all. Below this, the profile is more compact, and the slurry slime had shear strengths of up to 4.0 tonne/m².

The solids concentration of the slurry slime increased from a low of 32% at the uppermost section of the slurry slime profile to a high of 59% at the bottom.

PROPOSED CLASSIFICATION SYSTEM

Based on results of the *in-situ* Shear Vane tests, Mackintosh Probings and study of solids concentration

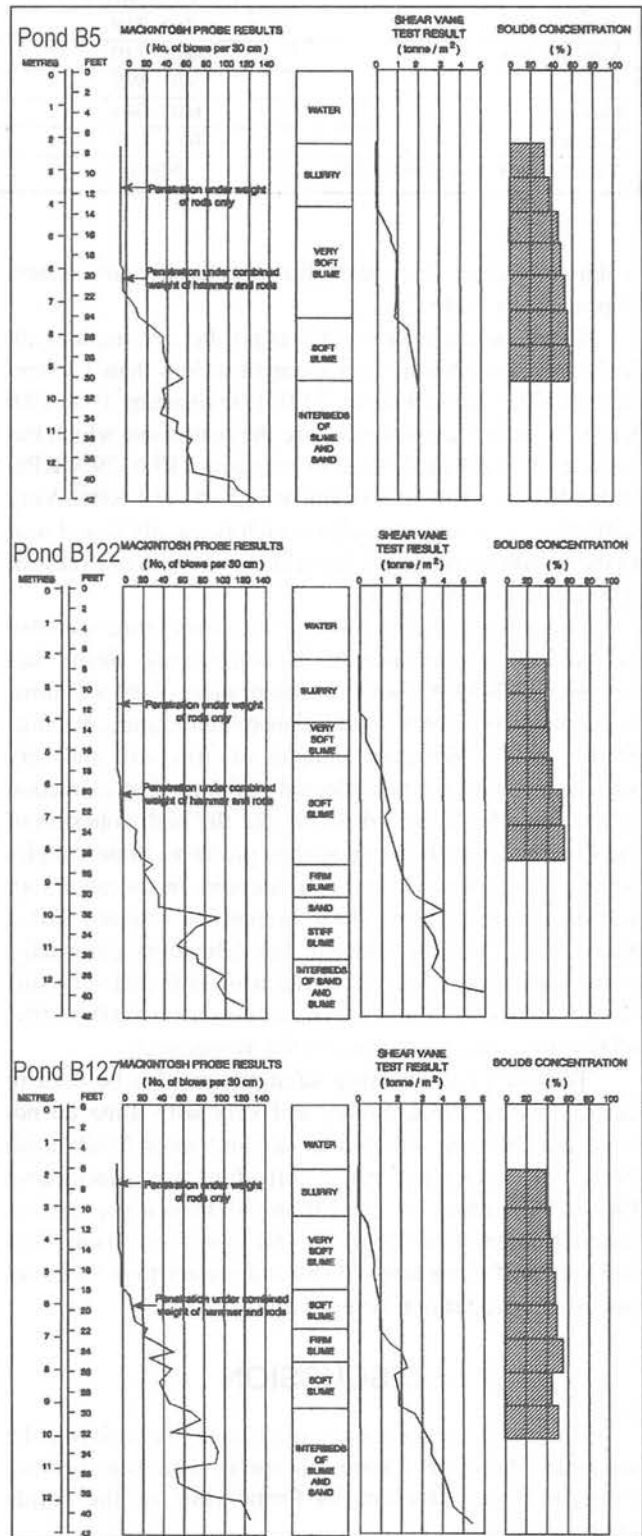


Figure 3. Solids concentration, bearing and shear strengths of slurry slime in Ponds B5, B122 and B127.

Table 2. Proposed classification system for slurry slime.

Classification	Solids concentration (%)	Mackintosh Probe test (No. of blows/30cm)	<i>In-situ</i> shear strength tonne/m ² (Kpa)
Slurry	30.0 - 39.9	0	0 (0)
Very soft slime	40.0 - 49.9	0	<1.00 (9.8)
Soft slime	50.0 - 59.9	<30	1.00-1.99 (9.8-19.5)
Firm slime	60.0 - 64.9	30 - 60	2.00-2.99 (19.6-29.4)
Stiff slime	65.0 - 69.9	61 - 80	3.00-3.99 (29.5-39.1)
Very stiff slime or compacted clay	>69.9	>80	>3.99 (39.1)

within the various strata, the following classification system is proposed (Table 2).

Slurry, which is very soft has no shear strength at all. Very soft slime has a shear strength of less than 1 tonne/m² (9.8 KPa) and soft slime, 1.00–1.99 tonne/m² (9.8–19.6 KPa). Of higher consistences are the firm slime which has a shear strength of 2.00–2.99 tonne/m² (19.6–29.4 KPa) and stiff slime, 3.00–3.99 tonne/m² (29.5–39.1 KPa). Very stiff slime, or compacted clay which is usually found near to the bottom of the pond, has a shear strength in excess of 3.99 tonne/m² (39.1 KPa).

The solids concentration of the slurry slime can also be used as an indicator of its consistency. Slurry has between 30.0–39.9% solids concentration. Very soft slime has about 40.0%–49.9% solids concentration and soft slime, 50.0%–59.9%. However, samples of firm, stiff and very stiff slime could not be collected in the field as extraction of the slime bailor was difficult due the high cohesion of the slime at depth. To overcome the problem, slime samples were compacted to various consistencies in the laboratory and their corresponding shear strength were tested with a Shear Vane. Results showed that laboratory-compacted slime with shear strengths of the firm, stiff and very stiff slime would have solids concentration of about 60.0–64.9%, 65.0–69.9% and more than 69.9% respectively.

The use of the bearing strength can also be used to classify slurry slime. Slurry and very soft slime do not have any bearing strength at all and their Mackintosh Probe 'N' values are zero. Soft slime has Mackintosh Probe 'N' values of less than 30 blows per 30 cm penetration and firm slime, 30–60 blows per 30 cm. Stiff and very stiff slime have 61–80 and greater than 80 blows per 30 cm penetration respectively.

DISCUSSION

The use of shear strength as a means of classifying the slurry and the slime is more appropriate than using bearing strength (from Mackintosh Probe test) or the solids concentration.

Under the proposed classification system, slurry and very soft slime have no bearing strength (zero Mackintosh Probe values). Besides, should there be a thin layer of sand within the slime, the Mackintosh Probe values will increase drastically and as such, the consistency of the

slime will be classified as more dense than what it should be.

As for tests for solids concentration, it was not possible to collect samples of firm, stiff and very stiff slime with a slime bailor. To overcome this problem, drilling should be carried out with a mechanized drill rig mounted on a pontoon. Standard penetration tests can be carried out to determine the bearing strength of the slime and at the same time, undisturbed samples can be collected with mazier samplers. This method however, will be more time-consuming and more labour-intensive and hence, more expensive.

CONCLUSION

- (i) In all the eight ponds studied, the transition layer (Zone B) in which the water is murky with about 10% to 15% of solids concentration was not extensive, measuring only about 30cm thick. In all the eight ponds, there was a slurry layer (Zone C) beneath the pond water. This slurry layer varied in thickness from 1.3 m to 1.9 m in the 3 ponds which are remnants from dredging activities. In ponds which are derived from the palong method of mining, this slurry layer varied from 0.9 m (in Pond E814) to 3.1 m (in Pond B72) thick. Beneath the slurry is slime (Zone D). Slime in the three ponds which are remnants from dredging activities varied from 5.5 to 7.6 m thick. As for the five remaining palong ponds, the slime varied from 4.6 to 11.6 m thick. The basal sections of the ponds which are remnants from dredging operations are usually composed of interbeds of slime and sand. The bottom of ponds derived from the palong method of mining are sandy.
- (ii) A classification system for the slurry slime based on their shear strengths, bearing strengths (Mackintosh Probe 'N' values) and solids concentration is proposed. Slurry has no shear strength. The shear strengths of the very soft slime varied from 0 to 0.99 tonne/m² (0 to 9.7 KPa), and that for soft slime 1.00 to 1.99 tonne/m² (9.8 to 19.5 KPa), firm slime, 2.00 to 2.99 tonne/m² (19.6 to 29.4 KPa) and stiff slime, 3.00 to 3.99 tonne/m² (29.5 to 39.1 KPa). Very stiff slime which in fact, is compacted clay, has a shear strength in excess of 3.99 tonne/m² (39.1 KPa).

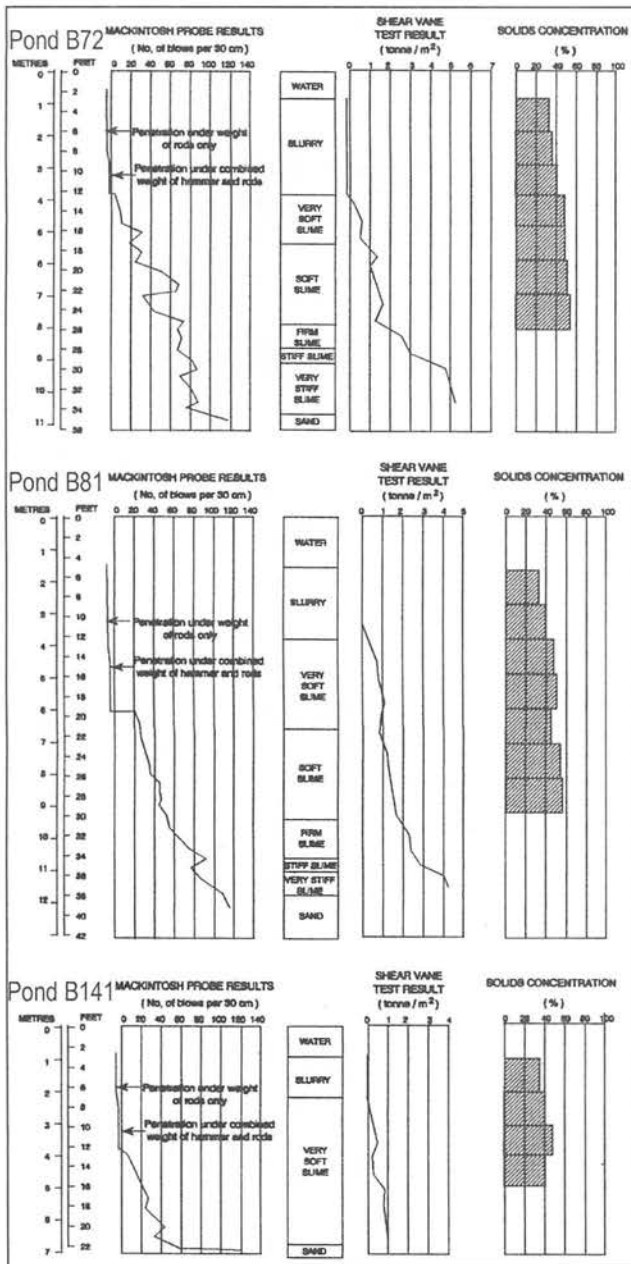


Figure 3. Solids concentration, bearing and shear strengths of slurry slime in Ponds B72, B81 and B141.

The bearing strengths (based on Mackintosh Probe 'N' values) of the slurry and very soft slime are almost negligible. Soft slime generally has less than 30 blows per 30 cm and that for firm slime, 30–60 blows per 30 cm. Stiff slime will have between 61 to 80 blows per 30cm and very stiff slime, more than 80 blows per 30 cm).

The solids concentration of the slurry and slime generally increase in tandem with their consistences. Slurry has about 30.0 to 39.9% solids concentration. Very soft and soft slime have about 40.0 to 49.9% and 50.0 to 59.9% solids concentration respectively. Firm, stiff and very stiff slime would have solids concentration-varying between 60.0 to 64.9%, 65.0 to 69.9% and greater than 69.9% respectively.

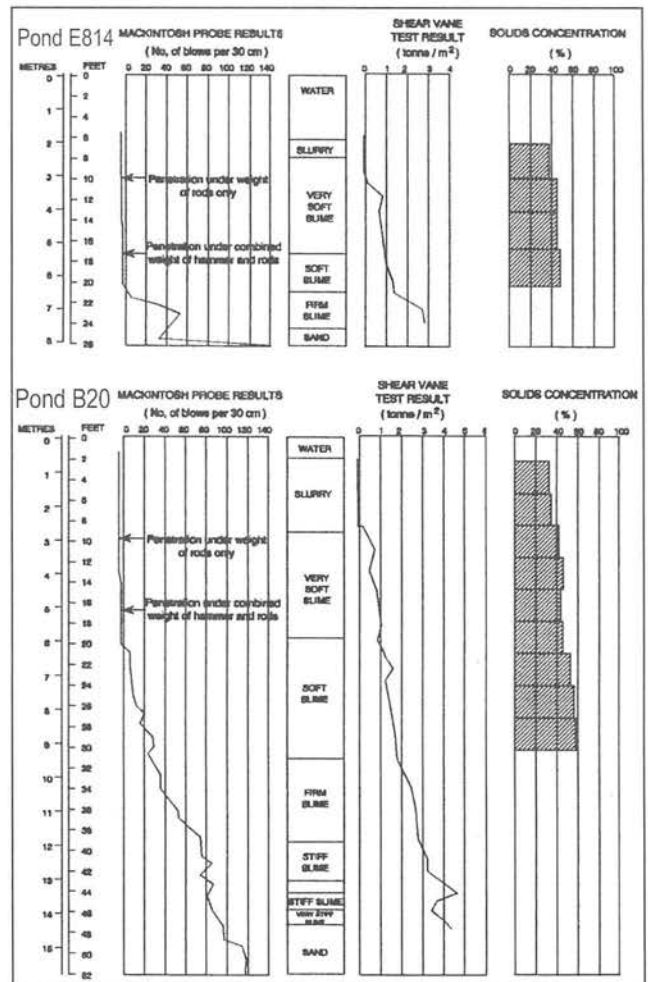


Figure 3. Solids concentration, bearing and shear strengths of slurry slime in Ponds E814 and B20.

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