Concrete without calcium or silica

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ABSTRACT

A new cementitious material with no calcium or silicate is studied. The cementitious material is a spent borax from metal refining plants. The spent borax shows a setting and cementitious behavior very similar to Portland cement but shows lower mechanical strength than OPC.

This paper gives the results of the mechanical strength, workability and loss of slump and the permeability of spent borax paste and concrete.

INTRODUCTION

The authors have an on-going research work for ‘Novel composite landfill liners’. This work seeks to produce a landfill liner system which comprises cement stabilised mineral wastes which is physically strong enough to support a refuse vehicle and yet maintains a permeability of less than 10^{-10} m/s. This will be achieved through the use of a clay based hydraulic barrier, sandwiched between two layers of concrete. The role of the concrete is two fold: the base layer will chemically condition solutions permeating through the liner, promoting crack healing through secondary mineralisation. Physically, its function is to support the clay membrane. The upper layer of concrete must physically protect the clay membrane from the local stresses of vehicles driving over its surface and from sharp objects in the waste (Figure 1).

One of the materials studied in this work was “spent borax”. The chemical composition of the spent borax from metal refining plants is based on sodium borate and various metallic oxides. Microscopic and XRD examination shows it to be comprised of around equal volume fractions of sodium tetraborate glass and metallic oxides (Figure 2). This is the first time that such materials have ever been used or studied, therefore no reference was cited in the literature concerning spent borax.

The ground spent borax (passing 150 microns) was mixed with aggregates and water in the same manner as Portland cement concrete.

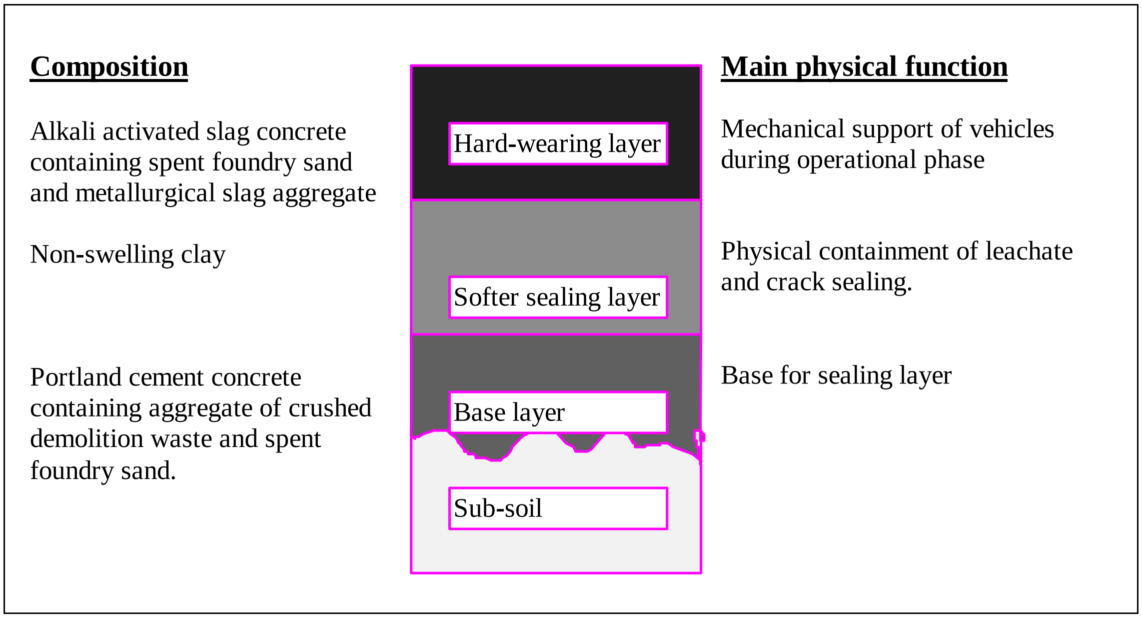

Figure 1: Schematic cross-section of composite landfill liner.

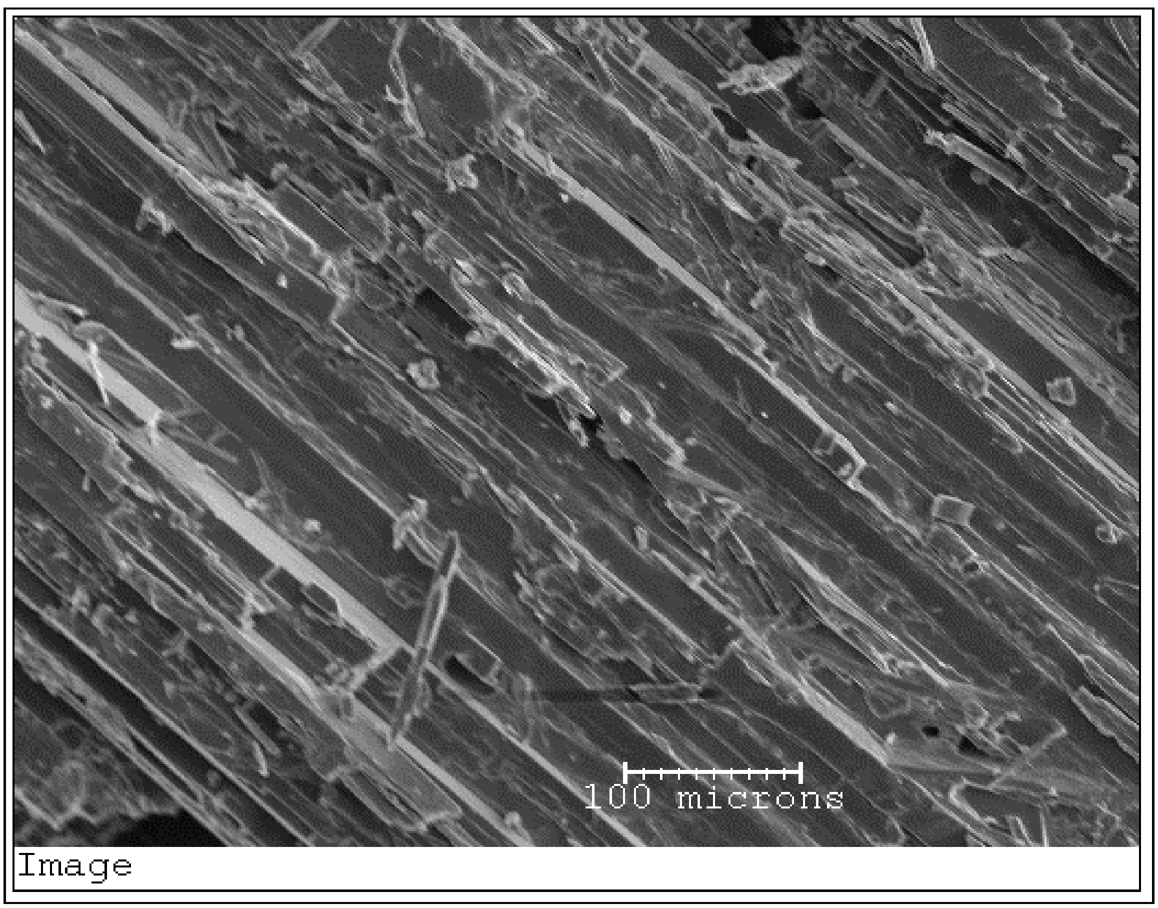

Figure 2: Secondary electron image of fracture surface of unhydrated slag.

SITE TRIAL

The ‘Novel composite landfill liners’ project includes carrying out large scale site trials to demonstrate the construction of the system and to assess the performance of the liner. The trials consist of cells of approximately 8 metres wide, which are designed to contain leachate to a depth of 1 metre, and are made with candidate barriers. The first cell has been constructed and filled and sampling lines within the barrier are being monitored. (Figures 3 and 4). The cell has been constructed with spent borax, limestone coarse aggregate and waste ferrosilicate as fine aggregate for the top layer which is 200 mm thick. The compressive strength at 28 days of this concrete was 5Mpa and its permeability was 1.7×10^{-9} m/s.

Figure 3: Emplacing the top layer spent borax concrete.

Figure 4: Finished landfill cell after compaction of spent borax concrete layer.

LABORATORY INVESTIGATION

The compressive strength of pastes (50 mm cubes) and concrete (100 mm cubes) was tested according to BS 1881, Part 116. The tensile strength of concrete was determined using 100 mm diameter and 200 mm long cylinders and tested according to BS 1881, Part 110. The workability of fresh concrete was determined by slump test according to BS 1881, Part 102. The specimens were cured either in water at 20 ± 2 °C or in the laboratory condition at 20 ± 2 °C according to BS 1881 Part 111. The permeability of the specimens has been determined using a continuous high-pressure flow experiment in which solutions may be eluted through the materials. The apparatus is a modified Hoek Cell and is adapted to measure both the flow and pressure drop across the sample (Figure 5). To maintain the structural integrity of the sample, and prevent flow past its sides a confining pressure may be applied (as in a triaxial cell) around an impermeable sleeve surrounding the sample.

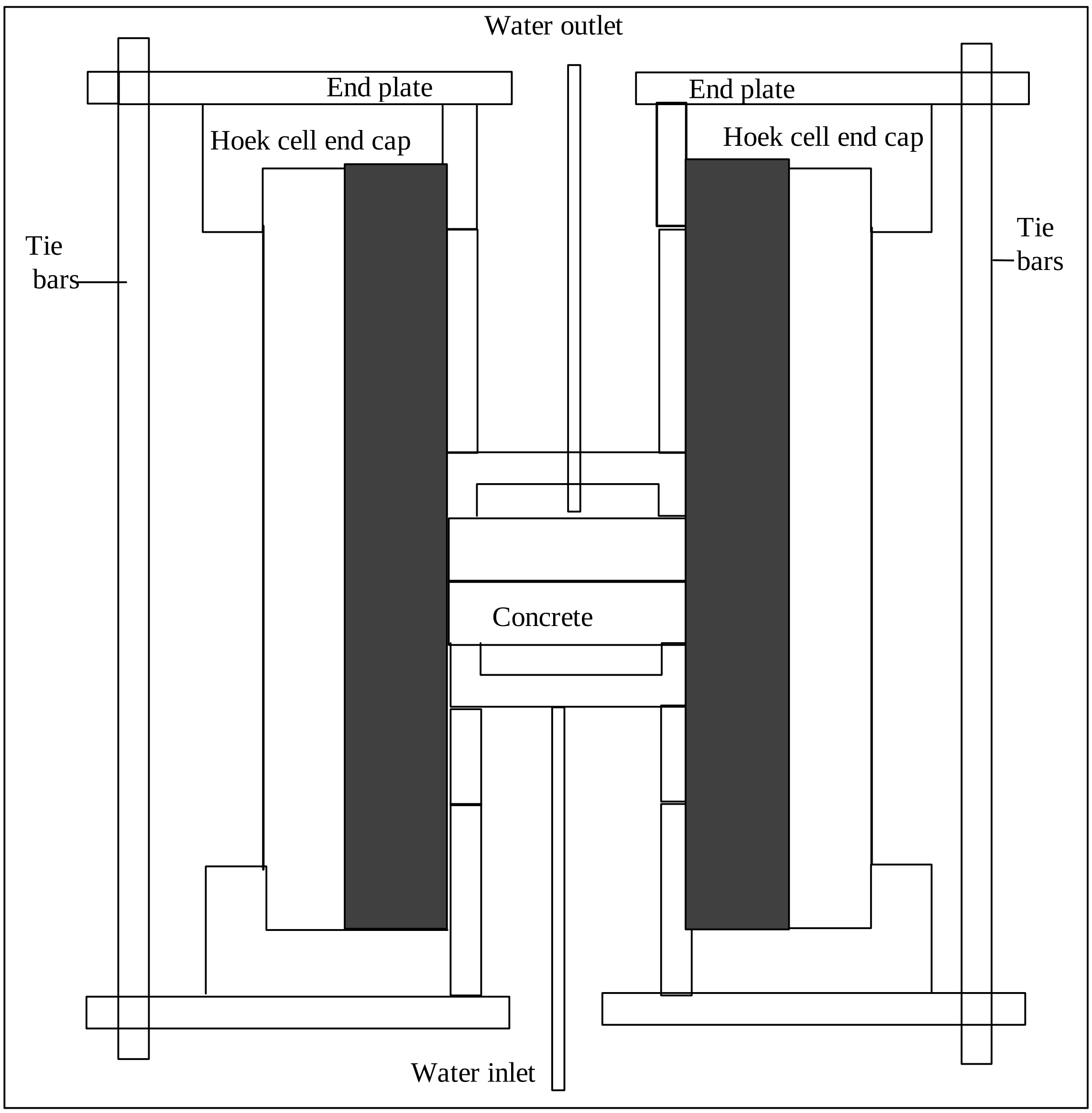

Figure 5: Schematic view of high-pressure cell

Both deionised water and a synthetic (acetogenic) leachate have been eluted through the materials to examine their effects on permeability evolution and buffering capacity of the concrete

Results

Spent borax paste with water to solid ratio of 0.25 was made and compared with ordinary Portland cement paste. The results of compressive strength (50 mm cubes) and hydraulic conductivity of these pastes are given in Table 1.

Table 1: Results of compressive strength and permeability of pastes.

	Water /solid	**Compressive strength at 28 days (MPa)**	**Permeability (m/s)**
Borax	0.25	45	5.6×10^{-10}
OPC	0.30	70	6.2×10^{-11}

Two different mix designs of spent borax concrete were made and compared with normal OPC concrete. The mix designs and results of these mixes are given in Tables 2 and 3 respectively.

Table 2: Mix designs and workability of concrete mixes.

	Cementitious (Kg/m^3)	**Water (Kg/m^3)**	**Fine agg (Kg/m^3)**	**Coarse agg (Kg/m^3)**	**Slump (mm)**	**Loss of slump to 0 mm (mins)**
Borax	450	255	765	960	140	150
Borax	550	287.5	765	960	210	90
OPC	420	200	765	960	80	50

Table 3: Compressive and tensile strength of concretes made.

	Compressive strength (Mpa)				**Tensile strength 28 days (Mpa)**		**Permeability (m/s)**
	Dry curing		**Wet curing**				
	7 days	**28 days**	**7 days**	**28 days**	**Dry**	**Wet**	
Borax 450	4.1	6.3	2.3	2.4	0.35	0.15	7.9×10^{-10}
Borax 550	3.4	5.5	2.5	2.8	0.5	0.4	6.2×10^{-10}
OPC			–	38.5	–	2.9	4.5×10^{-13}

Discussion

The spent borax paste has a strength and permeability which is comparable to OPC. The spent borax concrete has a good workability and shows same loss of slump as normal concrete and increasing the borax content reduces the setting time of borax concrete.

Curing the spent borax under water reduces the strength and slows down the hydration process. This is due to crack development in under water samples, but once the concrete has gained strength, it would not lose strength under water.

The backscattered electron image of polished surface of the 28 days hydrated paste of spent borax is shown in Figure 6. This shows that the fine particles (about one micron) have dissolved and re-precipitated as a product of low crystallinity.

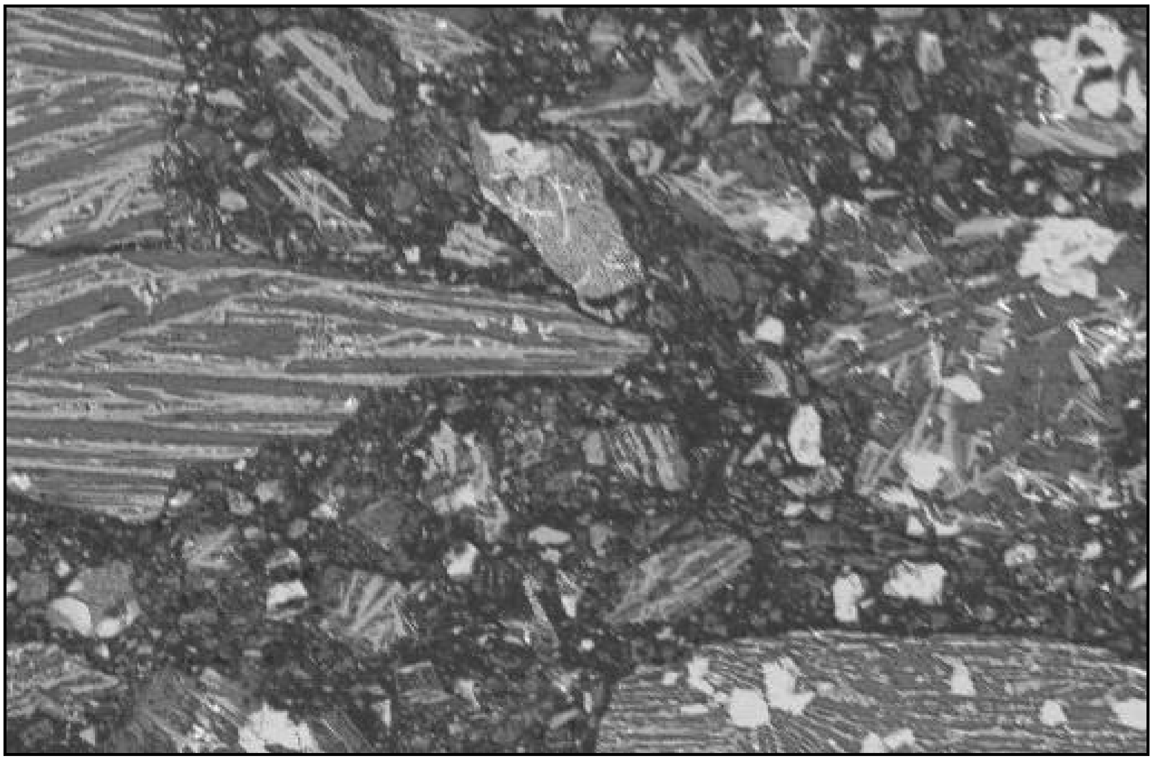

Figure 4: Backscattered electron image of polished surface of the hydrated spent borax paste (same scale as Figure 2). The white area is metal-substituted metallic oxide, the light grey area is metallic oxide, the dark grey area is sodium tetraborate oxide and the black area is fracture porosity.

CONCLUSIONS

The spent borax concrete is not proposed as a material for construction of major structural elements but it is indicated that it is suitable for the application for which it has been tested. The main advantage offered is that it is a waste material, which would otherwise have a substantial disposal cost and can therefore be used in combination with waste aggregate to produce negative value concrete.