Geosynthetics, J. Kuwano & J. Koseki (eds)

Case history: The use of electrokinetic geosynthetics (EKG) in belt press dewatering

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ABSTRACT: Belt press technology is widely used to dewater sewage sludge as well as other difficult materials having high water content such as mine tailings. This technology is limited by the pressure that can be developed between two filter belts and the hydraulic permeability of the material that is being dewatered. Electroosmosis has the ability to dramatically increase the rate of water flow in fine grained materials and this ability was investigated in laboratory simulations of belt press dewatering of sewage sludge and mine tailings. Data gathered from laboratory investigations were used to design a full scale electrokinetic belt press based on an existing machine with the specification that retro-fitting to existing machines is possible. A case history on the testing of such a design is described. Activation of the electrokinetic belts raised the dry solids content of the dewatered cake from 19% to >30% with an additional power consumption of around 8 kW. This represents a major increase in the performance of the machines at a relatively modest increase in power consumption and running costs. The potential for further increases exists. The benefits of increased dewatering include reductions in volume and improved mechanical handling. In addition, by raising the dry solids content above approximately 33–35% the material becomes autothermic upon combustion, thus significant savings in fuel during incineration may accrue. The development of electrically conductive belt press technology has been undertaken by Electrokinetic Ltd. and Ashbrook Simon Hartley Ltd.

1 INTRODUCTION

Dewatering mixtures of fine grained solids and water (known as sludges, slurries, pastes, muds, and slimes) is a technical challenge faced by hundreds of industries across the globe. In general, the effects of dewatering are the reduction of volume and improvements in mechanical handling, and the benefits include reduction in the costs of handling, transportation, and disposal or reuse.

Dewatering refers to the process by which a thickened liquid is transformed into a solid material (often termed a cake). In general terms, liquids can be pumped and solids are handled by means such as digging and conveying. For mixtures of solids and water, the transition from liquid to solid is rarely abrupt and this is especially so in materials such as sewage sludges. The role of dewatering is to jump the gap that exists between the liquid state and the solid state. This is achieved by removing water by a choice of methods, which vary in output, cost, quality, and ancillaries. In general, when transforming a liquid into a solid by dewatering, more effective dewatering moves a material further into the domain of the solids with concomitant improvement in strength and reduction in volume.

Most dewatering methods rely on the movement of water down a hydraulic or pressure gradient, which, together with the hydraulic permeability, controls the flow velocity. This relationship is known as Darcy's Law and the limitations it places on hydraulic flow in fine grained materials such as sludges and slurries are manifest in the difficulty of dewatering these materials.

This paper describes the laboratory and full scale application of electrokinetic geosynthetics to dewatering sewage sludges and mine tailings using a standard belt filter press.

2 PREVIOUS ATTEMPTS

There are a number of examples of the application of electroosmosis to belt presses, most of which were concentrated on dewatering of sewage sludge through a combination of electroosmosis with mechanical dewatering such as that produced by filter presses (Smollen & Kafaar, 1994; Gazbar et al., 1994; Miller et al., 1998). These studies showed that water in sewage sludge flocs is held in four forms:

- Free or bulk water (water between flocs);
- Interstitial water (physically trapped within flocs);
- Vicinal water (held by hydrogen bonding: immobile under mechanical means only); and
- Chemically bound water (removable thermally).

It is understood that electrokinetic techniques (principally electroosmosis) have the ability to move free, interstitial, and vicinal water, and thus have an advantage over pure mechanical methods.

Electroosmosis may be used in combination with pressure-based dewatering method (belt presses) to improve the dewatering process by improving the removal of interstitial water and allowing the removal of some vicinal water. These studies showed that the electrokinetically enhanced dewatering of different sludges varied. However, the fundamental electroosmotic parameters e.g. k_e (electroosmotic conductivity) has not been generally defined. An exception is Yan & Weng (2002) who noted a k_e value about 5 times as that of many soils.

Research into electroosmotically enhanced belt press technology has not, hitherto, gained wide application for two reasons, either:

1. The belt materials have not been used as electrodes i.e. relying on the rollers to distribute current (which is inherently limited); or
2. Where an electrified belt has been used, this has been made from such materials that oxidise rapidly at the anode and thus raise issues of contact resistance, longevity, and contamination. Therefore, the target of fabricating a belt with the same filtration capacity as existing belts and corrosion resistance necessary to endure through a service life of several thousands of hours has been a major technical challenge.

Electrokinetic geosynthetics (EKG) were developed at the University of Newcastle (Hamir et al., 2001) to incorporate the benefits of enhanced water flow through electrokinetics with the functions of geosynthetics, in so producing a family of composite materials. EKG design has been used to a produce strong, durable filtration belts, which maintain the existing performance characteristics of established filtration belts.

3 CONTROLLING PARAMETERS

The conceptual model of a working belt filter press incorporating electroosmosis is shown in Figure 1. Here the material to be dewatered, e.g. sludge at a dry solids content of approximate 2–4% is fed onto the top belt where it drains under gravity. This gravity drainage is profoundly enhanced by pre-treatment with chemical flocculants.

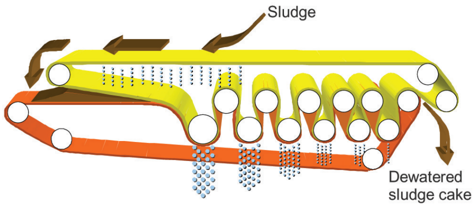

Figure 1. Conceptual model of belt filter press. Upper belt is the anode and the lower is belt the cathode.

In the parallel section the sludge is sandwiched between the upper (anode) and lower (cathode) belts. The creation of a voltage gradient across the sludge creates electroosmotic flow, which acts in addition to the hydraulic flow. The volume of water, *Q*, moved by electroosmosis in time *t* across area A is defined by Mitchell (1993):

$$Q/t = k_e \cdot (V/L) \cdot A \tag{1}$$

Where k_e is the coefficient of electroosmotic permeability, V is the voltage, L is the distance across which the voltage is applied. This can be re-written as:

$$Q/t = k_e \cdot \rho \cdot I \tag{2}$$

Where, ρ is the resistivity of the material and I is the current passed through.
Therefore, for a belt press of given dimensions, the parameters controlling the electroosmotic dewatering are:

- Voltage (V)
- Current (I)
- Resistivity (ρ)
- Separation of belts or sludge thickness (d)
- Residence time (t)

Voltage and current can be varied or controlled according to the electrical supply and the design of the belts (array of conducting elements). The residence time and sludge thickness are a function of belt speed and sludge feed rate. Controlling the resistivity of the sludge is considered unfeasible. Understanding the relationship of these parameters in the laboratory has been the key to achieving good results in field trials.

4 LABORATORY TESTS

The University of Newcastle performed a large number of tests on sewage sludge and mine tailings. These were conducted in electrokinetic test cells using EKG filtration electrodes. Normal stresses were applied to simulate the compressive force between the belts. Importantly, the dynamic environment in an active belt could not be simulated in a controlled manner. Figure 2 shows the electrokinetic dewatering of 15 mm thick samples of humic sludge. The variables

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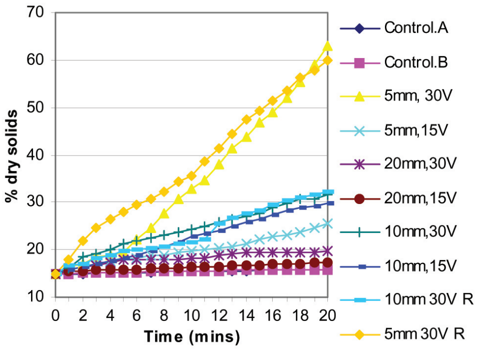

Figure 2. Laboratory electrokinetic dewatering of sludge.

included applied voltage, spacing of conducting elements in the electrokinetic filters, and residence time.

The data in Figure 2 were generated based on 15 mm thick sludge samples. These showed that the best performance was achieved using electrode filters with a pitch of 5 mm and a voltage of 30 V. These data also showed that after about 8–9 minutes (the upper reasonable limit for residence time in an operating machine) the sludge was dewatered to yield a cake of approximate 30%ds.

A similar approach to laboratory dewatering of mine tailings yielded the data in Figure 3. These experiments were all run at 15 V but varied the sample thickness, spacing of conducting elements, and residence time. Here the issue was to achieve a particular solids content, which would produce a particular mechanical behaviour.

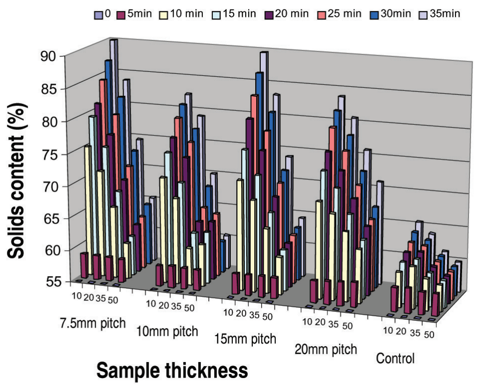

Figure 3. Laboratory electroosmotic dewatering of mine tailings.

A detailed analysis is not possible here but the data confirmed that dewatering performance for a given material and voltage was influenced by thickness, spacing of conducting elements, and residence time. This, therefore, offers the possibility to achieve the desired solids content and, at the same time, maximise the throughput by designing an appropriate belt and controlling the operating parameters of sample thickness, residence time and voltage gradient.

5 FIELD TRIAL

The next stage of the work was to conduct a full-scale field trial. At the time of writing, two field trials have been conducted on sewage sludge and a trial on mine tailings.

The sludge trials involved producing designs, which optimized the identified competing parameters. In terms of the parameters confirmed in the laboratory phase, it was considered that residence time and sample thickness in a working belt press would be adjustable over a relatively narrow range, with upper limits of approximately 10 minutes and 15 mm, respectively. Given these constraints and the relationships defined in equations 1 and 2, the effort was focused on voltage and belt design. The major challenges were to apply electricity to the belts and to configure the electrodes in the belt in such a way as to maximize the electrokinetic effects and thus dewatering performance. The belts were fabricated from woven polyester with metallic elements included to provide current discharge through the sludge and also a means of distributing current from the stationary power supply to the moving belts.

The trial of the electrokinetic belt press took place on site in southern England. The sludge was a mixture of surplus activated sludge (SAS) and primary sludge. Under normal conditions belt press dewatering of this sludge was producing a sludge cake of with a dry solids content of 18–20%. In order to maximise the dewatering performance the belt was slowed down such that the residence time in the parallel section of the belt increased from 5 minutes to 9 minutes. At the same time the feed rate (and thus throughput) was reduced by 10% such that sample thickness was increased significantly from approximately 5mm to approximately 10 mm.

Trials were performed over a 5 day period, the belt press was manned continually and the regular measurements of solids contents were taken. The primary aim of the trial was to evaluate the dewatering performance of the electrokinetic belt press (Figure 4) and to collect data to assess the overall power consumption (Figure 5).

Data collected from the inactivated electrokinetic belt press indicated that the machine was producing a cake of approximate 22% dry solids. This slight improvement on the typical performance of this machine (18–20%) was attributed to the installation of new belts and a slight reduction in the feed rate. Upon electrical activation however, it was seen that the solids content steadily improved with applied

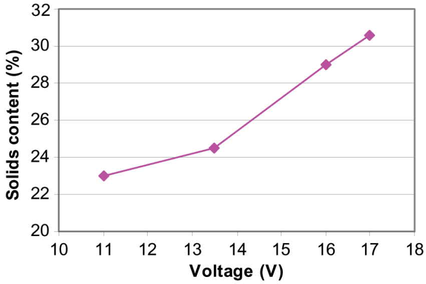

Figure 4. Dewatering performance of electrokinetic belt press on sewage sludge.

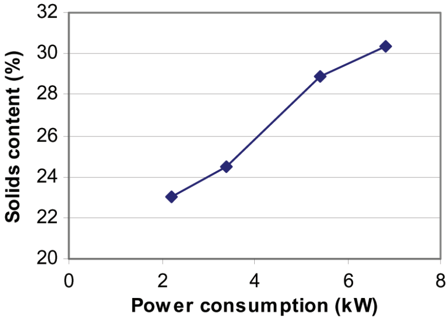

Figure 5. Power consumption of electrokinetic belt press on sewage sludge.

voltage (Figure 4). The solids content at discharge of approximate 30% represents a major improvement.

Activation of the electrokinetic belt press over the course of a week showed that for an average throughput of 14 m^3/hr at an average input of 2.5%ds, the power consumption yielded an additional electricity requirement of 19.5 kWhr/dry tonne. This modest power consumption means that the technology is well placed to compete with other methods of dewatering such as centrifuges, especially with the desire to reduce costs and energy consumption. There is also additional scope in the planned trials to characterize further the relationship between solids content and power consumption.

6 DISCUSSION

The main implications of the improved dewatering were cost reductions related to volume reduction and transportation, additional benefits accrued from better mechanical handling. Similar benefits will accrue to the dewatering of mine tailings. In other settings, raising the dry solids content of sludge above 33–35% opens the possibility for sludge to become autothermic, which would mean significant savings on fuel oil for sludge incineration.

The performance of the full-scale trial was better than would have been predicted from the laboratory experiments. This is attributed to the additional effects of shearing and the thinner sample thickness in the field trial compared to the laboratory studies.

7 CONCLUSIONS

The theoretical controls on electrokinetic dewatering of sludges and slurries have been identified and confirmed by laboratory testing. A full scale trial with sewage sludge demonstrated enhanced dewatering and consistent achievement of dry solids of greater than 30%. Subsequent trials for are planned to raise the voltage to extend the graphs in Figures 4 and 5. Trials are also planed for electrokinetic dewatering of mine tailings.

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