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

The use of electrokinetic geosynthetics (EKG) in enhanced performance of sports turf

Lamont-Black, J. & Huntley, D.T.
Electrokinetic Ltd., Newcastle upon Tyne, UK

Glendinning, S. & Jones, C.J.F.P.
School of Civil Engineering and Geosciences, University of Newcastle upon Tyne, UK

Keywords: sports turf, aeration, drainage, electroosmosis, electrokinetics, electrokinetic geosynthetics, EKG

ABSTRACT: This paper considers the effect of electrokinetic geosynthetics on the performance of natural sports turf. It is considered herein that electrokinetic treatment comprises electroosmotic water flow and electrolytic evolution of gas. When used on natural sports turf, the combined effects include control of water flow, pore pressure, pH and oxygen levels. Together these affect both the physical (performance related) characteristics such as water content, shear strength and ball bounce, and the biological (reliability related) characteristics such as aeration and pH control. Turf-grass health is determined by factors such as adequate drainage and aeration of the soil, sufficient light and the effective control of pests and weeds. The use of electrokinetic geosynthetics (EKG) in the management sports turf to enhance performance indices and reliability characteristics has been researched in the UK using natural (in situ) and constructed sports turf systems. Field data collected over a period of three years have shown that controlled application of electrokinetic phenomena using EKG provide several key benefits including: dewatering to influence water content, shear strength and ball bounce, and aeration of the root zone with increased root respiration and microbiological activity, adaptation of turf-grass to the stresses of low light levels (including improvements in root strength) and reduction in levels of thatch (excess dead organic matter).

1 INTRODUCTION

Electrokinetic geosynthetics (Jones et al., 2005) combine the established technologies of electrokinetics, discovered in the early 19th century (Reuss, 1809) with geosynthetics. Fundamentally the phenomena of electrokinetics describe the relative movement of water and solids under an electric field. There are several electrokinetic phenomena, the most important of which is electroosmosis (flow of water in soil under an applied voltage), as shown in Figure 1. The practical significance of electroosmosis for engineering is that it can greatly increase water flow velocities in low permeability materials. Figure 1 also shows the release of gases and pH changes, i.e. electrolysis. Electrolysis is not an electrokinetic effect *per se* but it is a direct consequence of driving a current through the ground. Although electroosmosis has been known for almost 200 years, its application in ground engineering has been limited due to electrode problems associated with electrochemical corrosion and the inability to effectively conduct the flow of water and gases. The advent of electrokinetic geosynthetics (EKG) has overcome these problems and added the functionality of electrokinetics to the established geosynthetics functions of drainage, reinforcement, filtration, separation and containment.

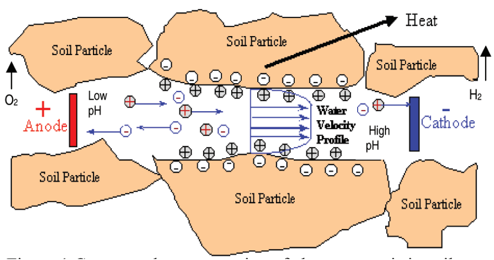

Figure 1. Conceptual representation of electroosmosis in soil.

2 RATIONALE FOR RESEARCH

The combined effects of electroosmosis (EO) and electrolysis (EL) include control of water flow, pore pressure, pH and oxygen levels. It was the realisation that these factors are some of the most important

Table 1. Rationale for researching EKG in sports turf

	Parameter	Effect	Importance for root zones
EO	Water flow rate $Q = k_e.V/L.A$	Drainage & water content	Improves drainage and permits more fines in root zone, important in surface preparation.
	Porepressure $u = (k_e/k_h).V/L$	Consolidation or Decompaction	Control performance of surface i.e. ball bounce and or ball speed.
EL	pH $\Delta pH = f.(I/A)$	Acid /alkali	Control of pests/ invasive species; sustainable non-chemical alternative.
	$[O_2]$, $[H_2]$ $\Delta [O_2], [H_2] = f.(I/A)$	Aeration i.e. Redox potential	Promotes root growth and soil microbial activity, reduces thatch, increases nutrient availability. Assists in decompaction.

Where:
K_e = Coefficient of electroosmotic permeability (m^2/sV)
K_h = Coefficient of hydraulic conductivity (m/s)
V/L = Potential gradient (V/m)
A = Area (m^2)
I = Current (A)
$[O_2]$ = Concentration of oxygen
$[H_2]$ = Concentration of hydrogen
f = denotes undefined function.

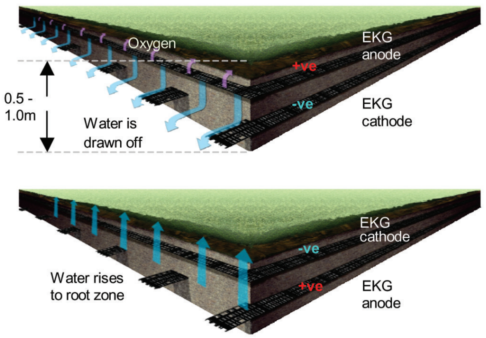

Figure 2. Conceptual model of EKG-turf system. Upper: normal polarity. Lower: reverse polarity.

issues in sports turf management (Table 1 and Figure 2) that led to the research in the area.

Under normal polarity, electroosmosis assists the natural downward drainage of water (Figure 2, top) and produces oxygen by water hydrolysis near the roots. In reverse polarity water is drawn up and hydrogen is evolved near the root zone.

The aim of the research was to examine the effectiveness of electroosmosis at influencing the soil characteristics and to examine the combined effects of electroosmosis and electrolysis on the health of the plants and the wider soil bio system.

3 NATURAL TURF TRIAL

The trial area comprised 130 m^2 section of a multipurpose pitch formed on clay loam over heavy clay glacial Till. It had been shown that one of the most important factors in implementing electroosmosis is the design of electrode array (Jones & Pugh, 2001). Cathodes were placed at 0.5 m centers at a depth of 0.5 m below four different anode arrays located at approximately 90 mm below the surface. The four anode arrays comprised:

- 'Mat' array (turf lifted, then replaced).
- 'Strips' 200 mm wide strips spaced at 200 mm (turf lifted then replaced).
- 'Narrow ribbons' 40 mm wide EKG ribbons spaced at 125 mm (installed by mole plough).
- 'Wide ribbons' 40 mm wide EKG ribbons spaced at 250 mm (installed by mole plough).

The characteristics of the site were established prior to activation. The four arrays were operated alongside control zones. Treatment comprised 3 and 6 hour activations of the system using a DC voltage gradient of approximately 0.25V/m.

Data were gathered from June to September on water content, shear strength, ball bounce, root zone CO_2 production, chlorophyll fluorescence ratio, root strength, thatch thickness, shoot growth and current. Evaluations were made as time-series of gradual changes, and as more discrete 'events'. The former generally related to plant health whereas the latter related to physical condition of the soil. Some of these data are shown in Figures 3 to 5.

Figure 3 summarises the changes in the parameters and indices for all the physical parameters of ball bounce water content and shear strength. This shows that in terms of observed changes before and after electrokinetic treatment, the test plots are ranked with the control area showing the least change followed by the strips then the wide ribbons then the narrow ribbons with the mat producing the largest changes. The difference in performance of the narrow ribbons and the mat was actually very small. Shear strength data were obtained using a hand held shear vane. In order to avoid potential damage, measurements were not made on the mat array.

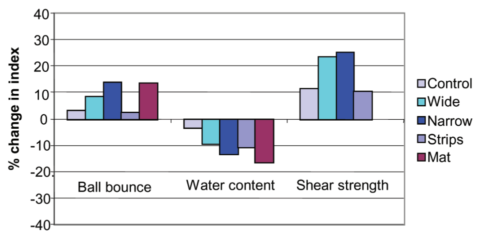

Figure 3. Summary of the performance EKG arrays for all treatments (shear strength data were taken for the mat array).

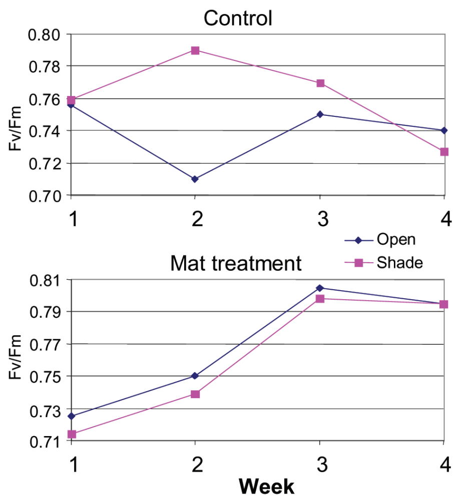

Figure 4. Chlorophyll fluorescence ratio (Fv/Fm) on natural turf.

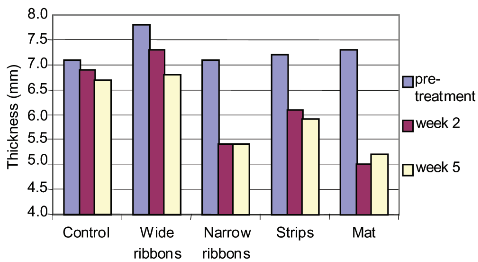

Figure 5. Thatch thickness measured before during and after electrokinetic treatment.

Chlorophyll fluorescence ratio Fv/Fm (CFR) is a measure of the efficiency of a plant's light harvesting mechanisms (photosystem II). Reduced values of the CFR indicate that the plant is under stress due to factors such as low light, drought, temperature and pathogens. Low light conditions, such as those experienced in many large stadia, were replicated by creating shade areas. Test results indicated that, as expected, the CFR fell in normal shaded zones. However, in the mat treatment area the plants responded such that the CFR was almost the same as in the unshaded areas. The implication of this result is that the electrokinetic treatment helped the plants to tolerate low lighting.

Thatch describes the accumulation of dead organic material (mostly cellulose), that occurs in and above the sward of the grass. The presence of thatch is undesirable because it inhibits drainage and can lead to a perched water table, reduces the rate of oxygen diffusion into the soil and reduces the mechanical performance of the surface. An excessive build up of thatch can be responsible for grass diseases, and invasion of weeds and poor playing quality.

Therefore, it is important to control this parameter wherever possible. In the tests conducted thatch was measured, before during and after electroosmotic treatment (Figure 5). These data show that, when compared to the control zones, thatch is reduced in all electrokinetic treatment areas except for the wide ribbons. Of the treatment zones, the mat produced the best reduction in the quantity of thatch. It is considered that the reduction in thatch is related to factors such as improved drainage and improved aeration (oxygenation) of the sward and root zone.

The data from the initial investigation showed that the application of electrokinetic phenomena to sports turf offered significant benefits in heavy clay soil for controlling and improving:

- Dewatering to influence water content and shear strength and ball bounce
- Adaptation to the stresses of low light
- Aeration of the root zone and increasing root respiration
- Improvements in root strength especially under the stresses of low light, and
- Reduction in thatch levels.

Comparison of the four electrode arrays showed that the mat and narrow ribbons provided the best performance. These arrays were equal in respect of ball bounce; the mat proved marginally better in terms of reducing water content but analysis of current data showed that the narrow ribbon array proved slightly better in terms of electroosmotic efficiency. The mat proved the best array for root strength and thatch thickness. It is believed that the biological benefits relate to direct oxygenation of the root zone due to electrolysis of water at the anodes. The higher performance of the mat area is related to the slightly higher unit area power consumption, which directly controlled oxygen evolution. Maximum power consumption in these tests was in the order of approximately 3.5 to 4.5 W/m^2.

4 SUSPENDED WATER TABLE PITCH

After demonstrating the effectiveness of EKG treatment on a clay-based sports pitch, the next stage evaluated performance on a sand based pitch. The surface chosen was constructed to the USGA specification for golf greens. The test site comprised two identical 6.25 m^2 sections of constructed sports turf surface. The profile shown in Figure 6, comprised an 80:20 mix of perennial rye grass and smooth stalked meadow grass on a root zone of medium sand with 10% fine sand. (known as Mansfield sand in the UK). The drainage layer comprised 10 mm gravel. The turf was allowed to establish on identical EKG mats for 3 months prior to electrokinetic treatment. The treatment comprised the application of a 24V potential for 3 hrs in the morning, five days a week for six months.

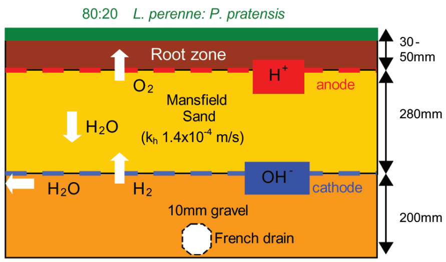

Figure 6. Profile of suspended water table pitch.

The data collected showed a distinct difference between the two halves of the constructed suspended water table pitch. The activated EKG half showed higher shear strength, ball bounce, CO_2 production, root mass, root strength, soil microbial activity and chlorophyll fluorescence. The unactivated half showed lower reductions in thatch thickness, pH and water content. There were no significant differences in temperature or yield. The microbiological results were of particular interest as shown in Figure 7.

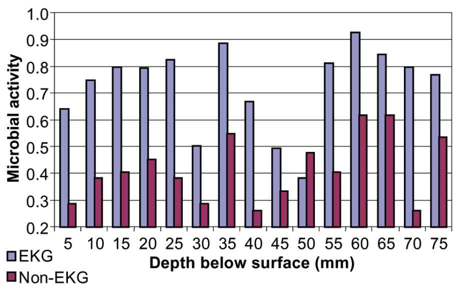

Figure 7. Microbial activity in the near surface root zone.

Microbial activity was assessed by quantifying the consumption of organic bait over a 20 day period. Each point on the graph represented 48 discrete measurements and showed a significant increase of microbial activity in the active EKG half. This activity correlated with reduced thatch thickness, greater root mass and greater CO_2 production in the active half compared to the inactive half, and is related to by evolution of oxygen at the anode.

5 DISCUSSION

The utility of electroosmosis in fine grained soils for producing consolidation and strength improvements is well established (Mitchell, 1992). The effects of electrolysis, especially in turfgrass systems is less well understood. The turf-soil system is a very complex and highly networked system. As a biological eco-system soil contains a large variety of micro and macro flora and fauna. The vast majority of these depend on oxygen to sustain them. In normal circumstances oxygen can only come from one direction i.e. the air above the soil. The health of the system is in many cases limited by the rate of diffusion of oxygen downwards. Therefore, together with the availability of water and sunlight, oxygen forms one of the fundamental parameters for the growth and health of turf grass.

The biological indices show that the application of EKG resulted in an increase in root–zone biological activity, CO_2 production and root strength, tolerance to shade and a decrease in thatch. It is suggested that the driver for these changes was an increased concentration of oxygen in the root zone. These correlate with physical effects, which included higher shear strength and ball bounce.

The implication of this is that EKG may provide a means by which to improve the physical performance of grass during the growing season but at the same time provide a greater root mass for the storage of carbohydrates to maintain health and the ability to repair wear and damage during the cold winter months. An advantage of the electrokinetic system is that it may be used much more frequently than traditional aeration methods, to provide oxygen where and when it is needed.

6 CONCLUSIONS

Research data has shown that active treatment with EKG was effective in turf systems grown on both clay and sand substrates, causing both strength-related and biological improvements to the system. Such improvements could obviate the need for extensive aeration operations. Electrical calculations indicate that power consumption would be low requiring only 1.8 kW to run treatments on 400 m^2 golf green or 27 kW to run a 6000 m^2 football pitch.

ACKNOWLEDGEMENTS

The Authors would like to thank the University of Newcastle Estates Department and the Institute of Groundsmanship for their support during the project.

REFERENCES

Hamir, R.B., Jones, C.J.F.P. and Clarke, B.G. 2001. Electrically conductive geosynthetic materials for consolidation and reinforced soil. Geotextiles and Geomembranes, 19(8), 455-482.

Jones, C.J.F.P., Pugh, R.C., Lamont-black, J. and Glendinning, S. in press. New Applications for Samrt Geosynthetics. Geofrontiers 2005, American Society of Civil Engineers, Austin Texas January 2005.

Mitchell, J.K. 1993. Fundamentals of Soil Behaviour. 2nd Edn., Pub. John Wiley & Sons Inc, New York, USA.

Reuss, F.F. 1809. Sur un nouvel effect de l'électricité glavanique. Mémoires de la Societé Impériale des Naturalistes de Moscu, 2, 327-337.