Institution: Newcastle University

Unit of Assessment: 14 Civil and Construction Engineering

Title of case study: Electrokinetic geosynthetics (EKG): revolutionising industry practice in infrastructure management and environmental impact reduction

1. Summary of the impact

The EKG technology developed by Newcastle has launched an entirely new spectrum of applications for geosynthetic materials and has resulted in changing established practice in civil, construction and mining engineering. The commercialisation of the technology, linking industry to applications of EKG products and processes, has been driven by the spin-out company Electrokinetic Limited. Amey, a leading international infrastructure services provider, incorporated the EKG technology into £1M projects for Network Rail and the Highways Agency in 2011-12. The end results were a 30% cost saving and 40% reduction in CO_2 compared to established methods. The new range of EKG products has been recognised by British Standards, leading to the revision of BS 8006 for reinforced soil in 2010.

2. Underpinning research

Electrokinetic (EK) Geosynthetics (G) were invented at Newcastle University, the concept being first introduced in an Invited Keynote Lecture at 3rd International Geosynthetics Symposium in Kyushu, Japan, in 1996.

The original EPSRC-funded research at Newcastle [**G1**] developed the overall concept of EKG and led to the first patent for its structure being granted in 1998. The research proved that EKGs could extend the applications of geosynthetics by adding an ***active*** component, substantially speeding up the movement of water in clay-rich soils. The Newcastle team achieved this by combining the electrokinetic phenomena of electro-osmosis, electrophoresis and associated electrokinetic functions with the traditional functions of geosynthetics of drainage, filtration, containment and reinforcement to form electokinetic geosynthetics (EKG). Publications were delayed until 2001 [**P1**] to protect the intellectual property and enable patents to be filed.

A second EPSRC award [**G2**] developed the applications for EKG in civil engineering and included several full-scale demonstration trials. This led to an increase in the number of structural forms of EKG patented as well as patents for their application. The main outcome of this research established that adding an ***active*** component to a traditional geosynthetic (such as a reinforcing element of a pre-fabricated vertical drain) substantially speeded up construction time and extended the range of soils that could be utilised, thus opening up new markets for geosynthetic materials [**P1, P2**]. Consequently, an EKG drain not only acts as a drain (a ***passive*** function), but also causes water in fine grained soil to flow to the drain (an ***active*** function) [**P1, P2, P6**] and EKG reinforcement ***increases*** the strength of the soil and the ***bond*** between the reinforcement and the soil [**P2**]. The field trials demonstrated that EKGs suffered no loss in performance or 'usability' when compared to traditional forms of geosynthetics.

Following the creation of the spin-out company Electrokinetic Limited (EKL) in 2000, research and development was conducted collaboratively between Newcastle University EKL who were able to lever TSB funding. Newcastle led the research effort required to develop and test new products and techniques while EKL dealt with the commercial application of EKG products and processes. Research concentrated on extending the application of EKG to roadside slope stabilisation and the treatment of large volume fluid wastes [**G3, G4, P4, P5, P6**]. New forms of EKG were developed, including EKG 'soil nails', EK belts (for belt filter presses) and EK 'filter bags' (for treating and disposing of small volume fluid wastes). All of these forms and applications have been patented. This work was led by Professor Glendinning which, as well as extending the markets for EKGs, also refined the understanding of their functions and added electrochemical components. This led to the definition of a new range of EKG materials, each with unique properties which could be controlled according to:

- Materials and settings in which the EKG is used;
- Physical and chemical design of the EKG;
- Electrical control and operation of the EKG;

- Management of the boundary conditions associated with the EKG.

Key personnel involved in this research were: Professor C J F P Jones (1986 - 2003) who pioneered the first work at Newcastle and played a key role in developing links with the geosynthetics industry and in establishing the spin-out company; Professor B G Clarke (1984 - 2008) who was involved in the first two research projects and the early stages of the spin-out; and Professor S Glendinning (1998 - current) who led the second two research projects and who manages the interface between research and practice. Contributing Research Associates include I M Nettleton (1995 – 1998), R Hamir (1994 - 1998), R C Pugh (1999 - 2002), C K Mok (2003 - 2006) and D Alder (2012 - present).

Details of the applications and key research publications are available from *www.electrokinetic.co.uk.* Research at Newcastle University has led the field of EKG research. Following the initial discovery work at Newcastle, further research/development programmes into EKG have been initiated in Australia (University of Western Australia) [**P3**], China (Wuhan University), France (Irstea-Unite HBAN), Germany (Sachsicestextil Forschungs Institute) and South Africa (Witwaterstrand University).

3. References to the research

Key Outputs: (3 key publications P1, P2 and P6)

[P1] Hamir, R.B., Jones, C.J.F.P., and Clarke, B.G., (2001) "Electrically conductive geosynthetics for consolidation and reinforced soil", *Geotextiles and Geomembranes,* **19** (8), 455-482. (The first Journal paper relating to the development of EKG.)

[P2] Glendinning, S., Jones, C.J.F.P., and Pugh, R.C., (2005) "Reinforced soil using cohesive fill and electrokinetic geosynthetics", *Int. Journal of Geomechanics,* **5**, (2), 138-146. (The paper describes the use of EKG technology to construct a full scale vertical reinforced soil wall built using a liquid fill, the fill was consolidated between construction lifts by EKG reinforcement)

[P3] Fourie, A.B., Johns, D.G., and Jones, C.J.F.P., (2007) "Dewatering of mine tailings using electrokinetic geosynthetics", *Canadian Geotechnical Journal,* **44**, (2), 160-172. (Details of the research using EKG to dewater mineral sands economically, the work led to the present study by Exarro to apply EKG technology to dewatering mineral tailings at an industrial scale of 200,000 tonnes/day)

[P4] Kalumba D., Glendinning, S., Rogers, C.D.F., Tyrer, M., Boardman, D.I. "Dewatering of tunneling slurry waste using electrokinetic geosynthetics". Journal of Environmental Engineering 2009, 135(11), 1227-1236

[P5] Glendinning, S., Mok, C,K., Kalumba, D., Rogers, C.D.F., Hunt, D.V.L. "design framework for electrokinetically enhanced dewatering of sludge". Journal of Environmental Engineering 2010, **136**(4), 417-426.

[P6] Jones, C.J.F.P., Lamont-Black, J., and Glendinning, S., (2011) "Electrokinetic geosynthetics in hydraulic applications", *Geotextiles and Geo-membranes*, **29**, (4), 381-390.(Requested by the International Geosynthetics Society (IGS) as EKG is recognized as a major development)

Key Research Grants:

[G1] EPSRC, GR/K20590/01: Research into new forms of geosynthetic materials, 1994 – 1997, £101,469. *PI: Prof Colin Jones*. Original research into developing EKG materials.

[G2] EPSRC, GR/L66090/01: Electrokinetic geosynthetic materials for use in the construction industry, 1997 – 2001, £212,187. *PI: Prof Colin Jones.* Took the results from the initial work (1994-1997) which developed the materials and developed applications in the construction industry - collaborators from UK, Sweden, Japan, Germany.

[G3] TSB (DTI Technology Programme as was), 15971: Treatment of wastes, slurries and soils with electrokinetic geosynthetics (EKG), 2005-2009, £1.4m. *PI: Prof Stephanie Glendinning.* Large consortium grant (nine partners) developing applications to waste industry. Companies involved exploit technology within their market. Substantially increased portfolio of projects and partners, opened up waste and mining to EKG.

[G4] EPSRC, GR/T04854/01: Fluid abstraction from liquid wastes for waste minimisation and resource recovery, 2005-2007, £92,269. *PI: Prof Stephanie Glendinning.*

Patents: 10 Patents covering EKG materials and applications, granted 1998-2013 in nine countries (**E2**).

4. Details of the impact

Research at Newcastle University led to the invention of EKG, creating a worldwide market for its use in designing a new range of 'active' geosynthetics. As testified by the Geotechnical Director of Tony Gee and Partners **(E1)**: "*Before the Newcastle University initiative there was no commercially available means of carrying out electro-osmosis*." The impact of EKG has brought about significant changes in civil engineering industrial practice, evidenced by revisions to UK standards [BS8006] and international guidelines. These changes have enabled a range of international companies in the civil engineering sector to gain a competitive edge in the market. There is rapidly growing impact in the mining, water and geoenvironmental engineering sectors.

1. Changing civil engineering practice and catalysing new companies

Electrokinetic Limited (EKL, www.electrokinetic.co.uk) was spun out of Newcastle University to pioneer the commercial application of EKG products and processes. EKL has attracted three rounds of private and venture capital funding totalling £510k as well as grant income from DTI (now TSB [**G3**]) and a Smart Award. It is the owner of an extensive family of patents relating to EKG materials, applications and methods. EKL have won commercial contracts utilizing these products totalling £694k in the last three years. The success of these contracts has brought about a major change in civil engineering industrial practice.

The major impacts to date have been on the civil engineering companies which have developed new practices for the design and installation of EKG slope repair of geotechnical transport infrastructure (Amey, Volkers, Balfour Beatty, Mott MacDonald, Birse Rail, Tony Gee and Partners, Luddon), and in the supply chain for material and equipment for these installations (Geotechnical Engineering Ltd., Electroinstall, Samuel James, TTI Ametek Ltd., Thandar, Leeds Transformers, Fuseland Ltd., Interserve).

New machinery has been developed by Geotechnical Engineering Ltd. to enable the installation of EKG in slopes; an entirely new company, Electro Install Limited (www.electroinstall.com), was set up in 2013 to capitalise on the new market in EKG-slope remediation which has been established by Newcastle. Furthermore, the transport infrastructure owners and operators (Highways Agency; Network Rail) which have adopted the new technology over more traditional approaches now recognise the significance of EKG for cost and environmental impact reduction in their businesses, as evidenced by the receipt of the Highways Agency (HA) supplier recognition award in 2012 [**E3**] (highlighting the important contributions made by suppliers to the HA strategic road network).

Amey is a market leading infrastructure services provider who worked with Newcastle University and EKL on the use of the electrokinetic remediation technique. The Technical Director of the Amey geotechnical group commented on the work [**E4**]: "*The Electrokinetic remediation technique has been demonstrated in a pilot project for Network Rail (NR) and at commercial scale on two highways projects for the Highways Agency (HA) completed in 2011 and 2012 , including the Amey led Area 9 M5 J7 scheme (approximate value £975,000) which recently won several industry awards (2013). Amey's Geotechnical team and EKL have collaborated on joint marketing, promotional and project development activities and signed a Confidentiality Agreement in February 2013. Amey and EKL have promoted the technique as a treatment option to the HA, NR, Sheffield PFI and South Lanarkshire Council (SLC). SLC have commissioned Amey in May 2013 to engage EKL as a sub-consultant for the design and supervision of electrokinetic remediation on the A72 Mauldslie slope remediation project (approximate value £350,000).*"

Amey conclude by stating the commercial impact of the EKL technology "*...is an improved market position in the UK for slope remediation and an enhanced reputation for innovation, which adds value to our bids for major infrastructure service contracts. It also provides business development opportunities for new infrastructure (including waste) customers in the UK and overseas.*"

2. Revising civil engineering standards and international guidelines

The new range of EKG products has been recognized by British Standards which led to the revision of BS 8006 (2010) covering the construction of reinforced soil structures, specifically accepting electrokinetic improvement of fill materials. The former Chairman of the British Standards Committee B526/04 Reinforced Soils supports this evidence by commenting [**E5**]: *"The revised Code of Practice BS8006-1:2010 allows the use of new products such as EKGs in the construction of reinforced soil structures used in many infrastructure projects such as: roads,*

railways, airports, industrial developments and waste disposal sites". This revision to the Code has enabled more wide-spread (worldwide) adoption of the technique. The International Geosynthetics Society accepted EKG as a new form of geosynthetic material in 2009 and has developed a new EKG symbol for use in contact documents and drawings [**E6**].

3. Reducing cost and environmental impact of major infrastructure assets

In relation to the electrokinetic remediation work, Amey highlight the major advantages as [**E4**]:

- *Cost Effective (typically 20 – 30% cost saving);*
- *No line possession or traffic management required during treatment;*
- *Low staffing levels means low H&S risk;*
- *Reduced carbon emissions (typically 40% less than other methods);*
- *Reduced environmental impact and no waste to landfill.*

This was further endorsed by the receipt of a Green Apple award [**E7**] for Environmental Sustainability. Furthermore, the Newcastle development of EKG has made it possible to meet a major objective of the revised BS 8006 by enabling the greater use of previously unacceptable waste materials into soil reinforcement [**E5**], thus increasing the environmental benefits of EKG.

4. Licencing for manufacture of products for the civil engineering and waste treatment industries

Currently there are 43 material suppliers associated with the supply and manufacture of EKG materials, including overseas manufacturers Afitex (France), Arctitex (Sweden), Clear Edge (Sweden), GKD (Germany) and Technitex Sachsen (Germany). The CEO and owner of Arctitex describes a product that has been developed specifically for manufacture of EKG materials [**E8**]: *"A machine for production of electrodes for dewatering of embankments and insitu-treatment. Stand by capacity of 80 000 – 320 000 linear meter of electrodes depending on daytime or work in shift. This capacity would render an annual turnover of 470 000 €".*

GKD have manufactured an EK belt press for waste treatment applications and Arctitex have manufactured a "*lining material for dewatering bags* (waste treatment) *with a market potential of 280 000 linear meters of bag material rendering a 5 320 000 € potential annual turnover"*

5. Extending applications and growing impact in the waste water and mining sectors

Successful full-scale trials of EKG-enhanced belt press have been conducted for two major international mining companies with the aim of drastically reducing waste volumes, increasing safety of waste disposal facilities and reducing water usage by recycling from waste back into processing. Referring to this technology, the managing director of GKD (UK) Ltd. [**E9**] states that: "*EKB has proven a successful technology*" and "*contributed dramatically to their environmental management of mining waste water*".

Amey support this impact by stating: "*Another different market area for Electrokinetic also exists that has not been as well developed as slope remediation, namely dewatering of wastes such as tailings and slurries. The opportunity for electrokinetic dewatering of slurry lagoons, mine tailings and similar wastes is potentially huge*."

5. Sources to corroborate the impact

[**E1**] Endorsement: Geotechnical Director (Tony Gee and Partners LLP, Network Rail Consultant)

[**E2**] First Patent GB2301311 "Improvements relating to Geosynthetics" & 9 further related patents.

[**E3**] HA 2012 Suppliers Recognition Scheme: http://press.highways.gov.uk/Press-Releases/Trailblazing-project-on-major-Kent-road-scoops-awards-67c0c.aspx

[**E4**] Endorsement from Technical Director - Geotechnics Consulting, Amey

[**E5**] Endorsement: Tech. Director (Geotechnical), AECOM & Chairman of BS 8006 review panel

[**E6**] International Geosynthetics Society (2009) Recommended Descriptions of Geosynthetics Functions, Geosynthetic Terminology, Mathematical and Geophysical Symbols, P9, 5th Ed.

[**E7**] Green Apple Award: http://www.electrokinetic.co.uk/news.htm#HAaward

[**E8**] Endorsement from CEO and owner of Arctitex, (Sweden)

[**E9**] Endorsement from Managing Director, GKD (UK) Ltd.