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Prof Andries B Fourie
BSc(Eng), MSc(Eng), PhD

BIOGRAPHICAL NOTE

Prof Fourie is a Professorial Fellow with the Australian Centre for Geomechanics (ACG) at the University of Western Australia in Perth, Australia.

His previous appointments include Professor of Construction Materials at the University of the Witwatersrand, South Africa, and Professor at the Rand Afrikaans University, South Africa.

The ACG provides independent research, consultancy and training services to the Australian mining industry, specializing in aspects of mining geomechanics. It was established in 1992 and enjoys an international reputation for the quality of the services provided.

Prof Fourie has worked in the field of environmental geomechanics and mine tailings management for 25 years and published over 100 referred articles in these and related fields. He has consulted on projects in a number of countries including Australia, South Africa, Zimbabwe, Peru and Canada and is on the editorial board of four international journals in the field of geotechnical engineering. He has conducted research and development on the use of electrokinetics for the dewatering and stabilization of soft clays and mine tailings, and has received several awards for his research and publications.

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FINAL REPORT

MULTI-PULSE SEQUENCING SYSTEM

HYDROTECH INTERNATIONAL LTD

Prof Andries B Fourie

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1. INTRODUCTION

This report provides an independent evaluation of the Multi-Pulse Sequencing system ("the MPS System") that has been acquired by a subsidiary of Hydrotech International Limited (HTI) with a view to developing the system for the effective treatment of water ingress and dampness in below-ground structures.

2. TERMS OF REFERENCE

I have been requested by HTI to provide an independent expert report on the technical merits of the MPS System and in particular to undertake:

- background investigations and reporting on the theory and historical development and application of the basic technology;
- investigations and reporting in relation to the science and theoretical application of the MPS system; and
- investigations and reporting on the practical application of the MPS System and whether it achieved predetermined objectives.

I made the enquiries I considered necessary to properly assess the technical merits of the MPS System which have included discussions with the technical and other personnel of HTI located in Europe, in particular Mr Henning Syversen, review of data provided by HTI, and discussions with personnel who have conducted a trial using the MPS system at the Walthamstow site in the United Kingdom in a subway operated by a major London public transport operator.

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3. BACKGROUND

In many parts of the world, structures that have been built below ground level (such as basements and tunnels) are prone to problems with ingress of moisture from the adjacent soil or rock mass. This is particularly prevalent when the adjacent soil or rock is saturated, for example because the water table is close to the surface or the structure is below a river (as with a transportation tunnel).

This ingress of moisture can cause problems that include:

- damage to and deterioration of surface finishes such as plaster, paint or tiling;
- deterioration of the reinforcing steel within the concrete as a result of corrosion;
- an increase of the relative humidity within the subsurface structure, which can lead to problems with equipment or deterioration of material stored in the structure (such as documents stored in a basement library).

Subsurface structures in contact with saturated soil or rock occur throughout the world and damage associated with the problem of moisture ingress to these structures results in costs of several million dollars per year.

Most conventional solutions are based on trying to waterproof the buried structure. When the problem only becomes apparent some time after construction (which is very common), only the inner face of the concrete basement or tunnel is available for treatment. When the potential problem is recognized before construction takes place, the outer wall may be treated. Treatments usually require the application of some sort of waterproofing substance such as bitumen. It is very difficult to ensure application is completely consistent and there are many examples where implementation of this approach has been unsuccessful. It is particularly difficult to apply a waterproofing substance to a surface that is already very moist, such as would occur in a structure where moisture ingress is already a problem.

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4. DESCRIPTION OF THE MPS SYSTEM

The MPS System utilizes the principle of electroosmosis, in which water can be caused to move through the pores, or capillaries, of a material such as clay, silt or concrete (amongst many others) under the action of an electrical potential. This flow can be caused to occur in the opposite direction to the flow that occurs under gravity, which is usually referred to as hydraulic flow. In material with very small pores or capillaries, such as the London Clay encountered at the Walthamstow site, the rate of water flow can be up to ten thousand times faster than the flow rate that would occur due to hydraulic flow.

Electroosmotic flow occurs when a voltage is applied between two electrodes, which must be made of conductive material. Typical materials are steel and copper. The electrochemical reactions that occur can result in rapid corrosion of the anode and for this reason the MPS System uses titanium wire as the anodic material. The negative electrode, the cathode, is not subjected to corrosion and hence the MPS System typically uses copper spears (or spikes) as the cathodes.

In a typical installation, rows of anodes are installed on the inside wall of a basement cavity and a much smaller number of cathodes installed in the soil immediately adjacent to the outside wall of the basement. The distance from the outside wall to the cathode may be as little as 10 centimetres. In one particular MPS System installation, the favourable ground conditions meant that only one cathode spear was required to produce the electrical connectivity required for the system to operate, making installation very quick and straightforward. Once the installation is complete, the electrical field causes water to migrate away from the anode towards the cathode, or indeed towards the water source that has received the negative charge of the cathode. Through use of a propriety control system, the MPS System applies a pulse of positive voltage, followed by a shorter period of negative voltage and a small rest period, after which the cycle begins again. It is the control system and its implementation that makes the MPS System unique.

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5. EVALUATION

The concept of electroosmotic flow of water is probably counterintuitive for many engineers. Conventional (hydraulic) flow of water depends on the pressure driving the flow (such as a difference in water elevation between two points) and the resistance to flow, which increases as the capillary size reduces. It is therefore natural to be skeptical about claims that the rate of flow under an electroosmotic gradient (i.e. a voltage) is virtually independent of the capillary size. However this is precisely what happens. For a given voltage gradient, water will flow just as rapidly through clay with very small capillaries as it would flow through beach sand, for example. Once this phenomenon is appreciated, the reason that the MPS System works as well as it does becomes more obvious. My comments in relation to the effectiveness of the MPS System are set out below.

Electroosmotic control of water is not a new concept, which is another misconception that must be laid to rest. It is over 50 years ago that an eminent geotechnical engineer by the name of Casagrande experimented with the technology, using it to stabilize soil slopes. In 1967 the Scandinavian engineer Laurits Bjerrum described a project in which electroosmosis was successfully used to dewater an excavation in very soft, weak Norwegian clay. In the geotechnical engineering literature there are sporadic articles describing use of electroosmotic systems in a wide range of applications, most of which involved the removal of water from a soil. However, these systems have not been widely adopted. So if the technology is not new (which it is not), why has it not become more widely used in the engineering industry?

One of the major reasons for the lack of take-up is, in my opinion, the crude nature of control systems used in the past. In most applications to date, a constant voltage has been applied, rather than using polarity reversal coupled with periods of no voltage application, or so-called pulsing flow. Pulsing flow has been shown to provide equivalent dewatering rates to constant voltage flow, but using less energy. I believe the key to the success of the MPS System is the short duration of the pulses that are used and the ability of the system to accommodate different ground and structural conditions by varying the pulse duration. The system also uses very low voltages (typically ± 20 V) and results in low frequencies, of the order of 1 Hz. The current that is drawn is also usually very low, and in my experience of electroosmotic dewatering of soft

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clays, it is usually in the range of milliamperes rather than amperes. This means that energy consumption rates are extremely low, with the amount of energy required to treat a 5 000 square meter section of basement being about the same as that required by a household light bulb.

The primary application of the technology to date has been in the prevention of moisture ingress to below-ground structures, typically basements. There are a number of examples of the use of the technology in Hong Kong by USIL Industrial Solutions (which is a fully owned subsidiary of USL) and there are additionally examples of earlier use in Norway by the original developers of the MPS System. These latter studies are not well documented and I therefore considered primarily the more accessible study of the Walthamstow site in London, for which physical measurements of relative humidity have been made to verify the effectiveness of the system. The Walthamstow example is, in my opinion, an extremely convincing example of the effectiveness of the MPS System. Under the circumstances at this site, which were not ideal for the application of the MPS System because a vapour-closed surfacing (a material that prevents the movement of air across the material) was applied to the inside face of the structure, it appears to be performing according to the expectations of the engineers who conducted the trial. The relative humidity (and therefore moisture content) of the concrete structure is approaching the required target level of 90% relative humidity over virtually the entire structure.

I understand that as long as certain conditions are met - the existence of a relatively continuous water source (such as a water table adjacent to a buried structure) and the existence of a medium (the concrete basement wall) that is effectively a series of connected capillaries - the MPS System will be well suited. In the case of a fractured or cracked medium (such as very heavily cracked concrete, or a fractured rockmass immediately adjacent to the structure), the MPS System cannot be expected to work satisfactorily, as is well recognized by HTI. The conditions required for successful implementation (available water source and capillary flow conditions) are not, however, a major restriction and will, in view of the large number of basements, tunnels and other structures around the world that are located in a suitable environment, be the rule rather than the exception.

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I expressed a concern regarding potential deleterious effects on adjacent buried services to HTI personnel. This issue, which relates to electromagnetic compliance (EMC), is recognized by HTI and they commissioned a series of EMC tests by York EMC Services Ltd. in the U.K. I am not able to provide an expert opinion on the results of these tests.

The MPS System is also effectively self-regulating, since as a concrete structure dries out to less than a certain relative humidity, the resistance to electrical flow rises proportionally, resulting in less current being drawn and a rapid decrease in the rate of moisture movement. This prevents the concrete from drying out too much, which could be damaging because it results in embrittlement of the concrete. On the other hand, if the relative humidity (and therefore the amount of water) in the concrete were to increase – perhaps in response to prolonged heavy rainfall injecting additional moisture to the outer surface of the concrete structure – the system should respond immediately to counter this moisture ingress. The increasing relative humidity will reduce the resistance, resulting in an increased current and increased rate of moisture movement away from the inside face of the structure.

Although installation of an MPS System requires a certain degree of quality control, it is not a particularly onerous procedure and is easily achieved. Once installed, there appears to me to be no obvious need for ongoing maintenance of an installation, and there is no obvious reason why it could not continue operating for many years without requiring any intervention. The ability to remotely monitor the system performance, which is a feature of the MPS System, adds another degree of confidence that successful ongoing applications are possible.

I could not identify any concerns that could be considered fatal flaws in the MPS System. My technical questions were all dealt with satisfactorily by Mr Henning Syversen and my only residual concern with the MPS System, which is minor, is the ability of HTI to recruit and train sufficient engineers to service the number of installations that could occur in the future, given the large number of buried basement and tunnel structures around the world.

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