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Developments in the use of an Electronic Leak Detection Geotextile (ELDEG®) for civil engineering and waste disposal purposes

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ABSTRACT: The author describes the widening use of a versatile system for detecting water passage through or from soil bodies in civil engineering structures such as dike bunds, building roofs and roof gardens. The interesting aspect of some of these developments is the use of the system as a detector of water passage, without the presence of an impermeable lining such as is used at the base of a waste containment structure. This paper also describes the newer utilisation of detection systems as an integral part of capping structures over finished waste disposal facilities.

1 THE ELDEG® SYSTEM

1.1 *Hardware configuration*

It is important to recognise that the ELDEG® system is not just a specialised method for assessing the possibility of leaks through impermeable liners beneath waste disposal facilities. In fact, it is a universal system for determining the location of liquid passage through any pre-selected two-dimensional plane in a constructed soil environment. Further, it has the facility to enable a qualitative analysis of the type of liquid passing through the detection plane, in terms of whether it is uncontaminated water, contaminated water or organic based liquid. A knowledge of the expected liquid composition helps in the assessment.

Essentially, the system consists of a minimum of three layers as shown in Fig.1. There is a specially chosen separator layer with cross-wired geotextiles on either side. The geotextiles can be chosen for their physical properties as well as being used to contain the detector wires for liquid location.

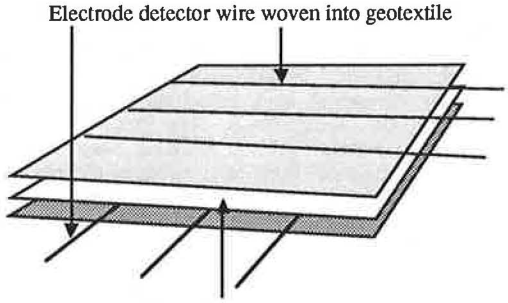

Fig.1 Electrode configuration in the ELDEG® system.

Conductor wires are woven into the warp direction of the detector textiles. The distance between the conductor wires is selected depending upon the accuracy of location required and the ultimate end-use scenario. Normally, detector wire groups are set every 0.5m within the textiles.

The separator layer is a normal nonwoven Polypropylene or Polyester based geotextile. Its function is primarily to act as an electric insulator. The electronic system utilises the capillary properties of the separator layer to ensure a rapid lateral dispersement of any liquid which reaches the separator, so that the cross-laid detector wires are quickly circuited.

The upper and lower detector layers are usually the same, but can be specified with different physical properties if required. The overlying rolls of textile are placed so that the upper and lower detector wires are at right angles to each other. With conductors at a distance of 0.5m., the accuracy of the system is such that it can pinpoint a leak within an area of $0.25m^2$.

Intelligent connector units are attached to the electrode detector wires on both the upper and lower layers. These intelligent nodes permit the simplified connection of the wires by a single cable, thus making connection quick, easy and reliable. The nodes are an intelligent, pre-programmed devices which perform measurement and communication functions. They transmit their data through the network to a central PC. On the opposite side of a detector layer, the wires are connected together with passive resistors.

Each node is connected to (and handles the data from) nine conductor wires. A simple four-core cable connects the nodes in parallel. This cable goes either from the field to an indoor PC running the ELDEG® program, or to a transmitting device which can send the information by radio signal to a remote PC for analysis and control.

1.2 *System operation*

The computer system interrogates the nodes, at frequent intervals. It takes about 18 seconds for a node to fulfil its task.

The following measurements are taken:-

1. Resistance between pairs of wires and resistance between immediately adjacent and cross lapping wires.
2. Capacitance between pairs of wires and between any wire and its local environment.

The resistance measurement gives an indication where a fluid is leaking through, but no quantification. The capacitance is in fact the measurement of the electrical permittivity. This is a recently developed method which gives an indication of the amount of fluid present between the electrode wires, provided that the fluid is water based. The electrical resistance of a fluid-filled porous medium can vary with both the amounts of fluid present and its conductivity. Therefore, a sudden increase in conductivity at any point might indicate either an increase in clean ground water or a small leak of conductive effluent. Therefore, the simultaneous measurement of capacitance is highly valuable in determining the relative constituents of the water or effluent and the two can be distinguished. After the system has been calibrated on site, these two readings together provide the required accurate and reliable answer.

2. APPLICATIONS FOR THE SYSTEM IN CONJUNCTION WITH MEMBRANES.

The original purpose of the ELDEG® system was to act as a leakage control system for waste disposal facilities. The system was designed to monitor the permeability state of membranes at the base of the landfill. If a leak occurs and the effluent reaches the separator layer, it is quickly dispersed by capillarity to reach the nearest two adjacent conductors, the interrogation values gathered by the nodes will change. On the screen of the PC a user-friendly map of the waste facility will show where the membrane is perforated.

The triple layer detector system is designed for use on the slopes of waste facilities as well as the base. The custom capability of the geotextile layers permits them to be designed for rugged use on slopes.

A new development, particularly in a number of European countries, has been the requirement for leak detection systems under the capping membrane which finally seals off finished waste disposal facilities. It is an essential part of the design of closed facilities that moisture ingress from rainfall is strictly controlled during the long period in which the waste material becomes inert. Calculations of gas and leachate production depend upon the amount of water expected into the waste. Leaks, therefore can cause serious problems in terms of increased running, venting and effluent disposal costs.

This application is very similar to that at the base of facilities, except naturally, the system is placed beneath the impermeable membrane instead of on top and also, the system need be less rugged than for the basal application. For use as a basal system, the impact of overlying weight and tension in the sloping elements calls for a higher strength specification. This can be relaxed in the case of capping detection systems where the type and shallow thickness of cover are pre-known and engineered.

Although not strictly a 'geotextile' use, there is a use for the system in the detection of leaks through flat roof membrane linings either from just a gravel covered standard roof or from roof garden systems which require regular watering. The problem is commonly encountered where water ingress is observed in the ceiling of a building, but the leak from above is not at that point. Very commonly, water in a ceiling moves sideways before manifesting itself as a drip in the room below. This is a major cause for concern in computer rooms in banks and other similar establishments. In the first instance, leaks are highly undesirable and secondly, the cost of locating a leak on a large roof can be considerable, if not impossible when it is covered in gravel or a garden. The system described in this paper is ideal for this purpose, since it can locate a leak immediately beneath a membrane with accuracy measured in millimetres. The accuracy can be increased as much as required by specifying a closer spacing of detector wires. The cost of the system in a roof situation is also rather less, since the physical specification of the textiles can be kept modest owing to the lack of weight and wear which it will be expected to suffer.

3. APPLICATIONS FOR THE SYSTEM NOT IN CONJUNCTION WITH MEMBRANES.

In the petroleum and chemical industry, a third application has become apparent. Health and Safety regulations and environmental considerations have necessitated the development of sealing bund systems around all large liquid containers such as petrol and oil storage tanks. The ELDEG® system can detect organic liquids of this kind and - usefully - differentiate them from clean water in the ground. Therefore, there is a useful application for the system to be placed immediately beneath large liquid storage tanks to give immediate warning of any leak and to pinpoint its position. Note that this application does not incorporate the use of a geomembrane, since it is not detecting the leaks

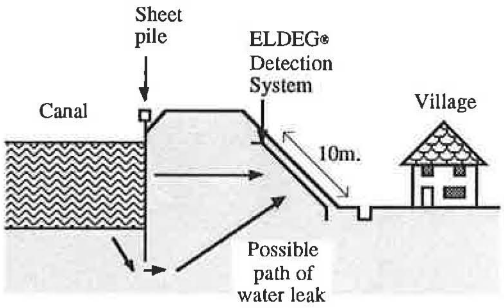

Fig.2 Cross section of canal bund with leak detection and location system fitted to detect incipient failure.

through one, but is rather detecting leaks from a container into the ground.

Another valuable application is the use of a detector system on the side slope of a dike, dam or water retaining bund. In many instances, the detection of early stage leakage can save a considerable amount of money in avoided repairs. Once a leak starts to occur in a bund, it can rapidly escalate in size as it washes soil out of the ground, thus increasing the size of its own flow path. In some cases, the consequences of failure of a bund can be more than just financial. In a number of cases, there can be danger to life if a bund were to fail and cause flooding of adjacent land. This scenario is covered in the case history given below.

4. CASE HISTORY - LEAK DETECTION AS PART OF A FLOOD PREVENTION SCHEME.

In Belgium, alongside a peaceful rural village, is a large dike bund, which is being refurbished. The inside of the canal is lined with interlocking steel sheet piles and when the canal has been re-dredged, it will hold a considerable body of free water. Of course, with canals generally, there is a considerable volume of water capable of outflow if damage should occur to the bank.

This is causing some concern to government organisations in terms of the possibility of leakage and failure of the bank. If this were to occur, then the adjacent village could be inundated and flooded, with serious potential for loss of life and consequent destruction of property.

A Belgian Government authority decided to install an ELDEG® leak monitoring system as illustrated in Fig.2.

In this installation, which was successfully completed within a few weeks, the detector system comprised the usual three textiles; two with detector wires and one to act as the capillary separator. These are laid over an area measuring 10m. up the slope, by 400m. along the length of the bank.

It is interesting to note that, for a long, thin installation such as this, there are more nodes required per unit area of surface covered than for a typical waste disposal facility, since those are usually more equal-sided. This process, although time consuming, was still completed promptly and without problem.

The leak detection system is now monitoring this critical bank and safeguarding the lives of the local community.

This system is ideal for such bund-side applications in many low-lying countries of Europe where communities are threatened by possible leakage from dikes. Advanced warning is the most effective weapon available to the engineer, since it is considerably cheaper to install an extensive warning system than to re-build entire lengths of dike, involving coffer dams and earthworks.

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